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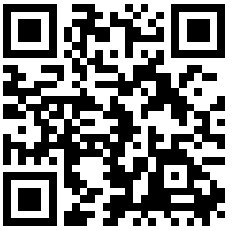

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Volume II—Part I

TANK GUNNERY

1930

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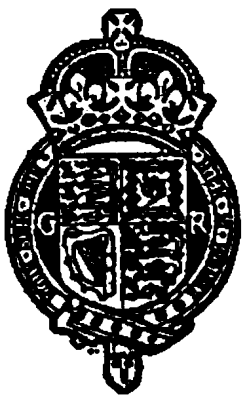

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TANK TRAINING

Volume II. Part I

1930

TANK GUNNERY

INTRODUCTION

1. The several parts of this volume, viz. :—

Part I.—Tank gunnery,

Part II.—Sequence in weapon instruction,

lay down all the necessary details of instruction in gunnery from that given to the recruit to that given to armament officers at the Gunnery School, both inclusive, with the following exceptions. The details of range practices are contained in the Handbook of Weapon Training, and the details of armament inspection and battle drill for a particular vehicle are contained in the Crew Drill for that vehicle.

2. Some of the more detailed instruction is applicable only to Light Tanks, Marks I, IA, II and IIA, and the

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Rolls-Royce Armoured Car. When new equipment is issued further instructions will be prepared. The principles and sequence of instruction laid down are, however, applicable to all types of armoured fighting vehicles likely to be produced in the near future.

DEFINITIONS

1. *Ballistical terms* :—

(The numbers in brackets refer to Fig. 1.)

Angle of descent (6).—The angle which the tangent to the trajectory at the point of impact makes with the line of sight.

Angle of impact (7).—The angle which the tangent to the trajectory at the point of impact makes with the tangent to the surface struck.

Angle of projection.—The vertical angle which the line of departure makes with the line of sight.

Angle of sight (3).—The angle which the line of sight makes with the horizontal plane.

Axis of the bore.—The line passing along the axis of the bore. This line may be slightly curved. Unless otherwise stated the axis of the bore signifies the direction of the axis at the breech.

Ballistics.—The science which deals with the motion of projectiles. It consists of :—

i. *Interior ballistics,* dealing with the motion of the shell in the bore of the gun.

ii. *Exterior ballistics,* dealing with the motion of the shell after it has left the muzzle.

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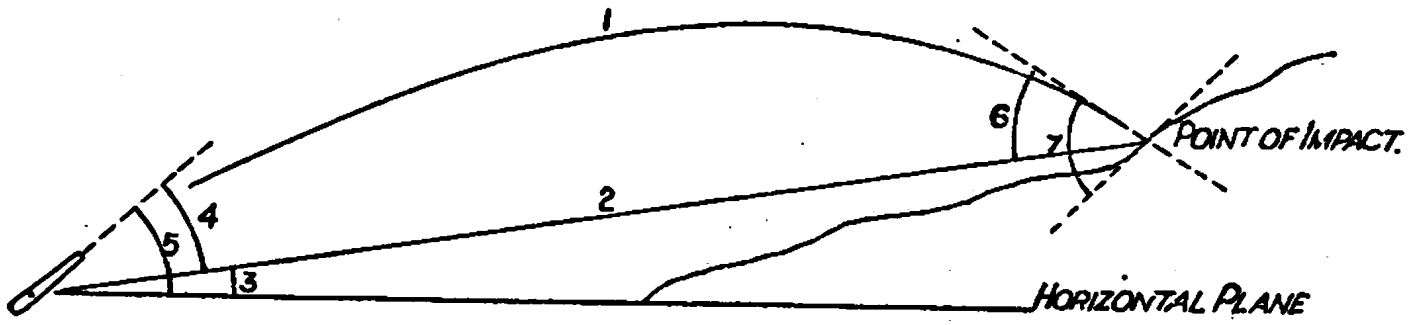
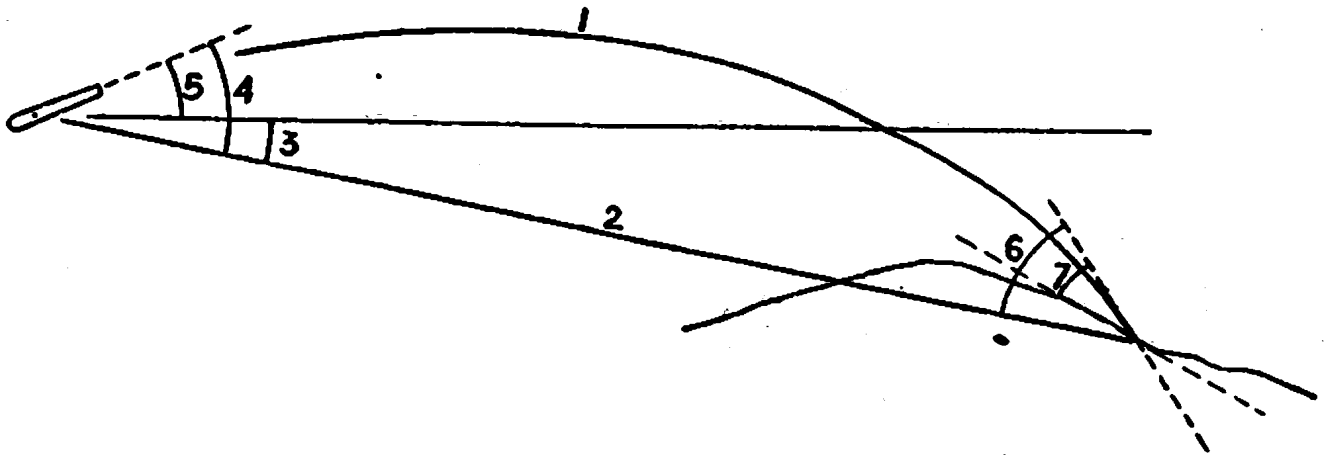
Ballistic coefficient is the measure of the power of a shell to maintain its velocity.

Drift.—The lateral displacement of the shell from the vertical plane in which lies the line of departure, due to its rotation.

Fig. 1.





Droop.—The vertical angle between the axis of the bore at the muzzle and the axis of the bore at the breech.

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Jump.—An angular movement of the gun in the vertical plane on firing, which affects the direction of the line of departure.

Laying.—The adjustment of the gun for direction and elevation prior to firing.

Line of departure.—The direction of motion of the shell at the moment of leaving the gun. It is the tangent to the trajectory at the muzzle.

Line of fire.—The direction of the target from the gun.

Line of sight (2).—The straight line passing through the sights and the target.

Mean point of impact (*M.P.I.*), is the centre of the pattern formed by the fall of a group of rounds with the same elevation.

Its position with reference to the target is usually stated in yards PLUS or MINUS, and RIGHT or LEFT.

Muzzle velocity.—The velocity of the shell, at the muzzle of the gun, expressed in feet a second.

Normal conditions are said to exist when :—

i.	Charge temperature is	60° F.
ii.	Air temperature is ...	60° F.
iii.	Barometer is	30″
iv.	Wind is	Nil.

Quadrant elevation (Q. E.) (5).—The angle which the axis of the bore, when the gun is laid, makes with the horizontal plane.

Range.—The actual distance in yards between two points.

Range table.—A table, or tables, giving all the data relative to the shooting of a particular type of gun.

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Remaining velocity.—The velocity of the shell or bullet at any point of the trajectory.

Striking velocity.—The velocity of the shell or bullet at the point of impact.

Tangent elevation (T.E.) (4).—The vertical angle which the axis of the bore, when the gun is laid, makes with the line of sight. The tangent elevation is often referred to as the "elevation." It may be expressed in degrees, or more usually in terms of distance in yards.

Time of flight.—The time the shell takes to reach the point of impact, reckoned from the moment it leaves the muzzle.

Trajectory (1).—The curve described by the shell in its flight.

2. *Terms used in tank gunnery :—*

Aim by selection.—The principle by which corrections for deflection or elevation are applied to a telescopic sight by aligning on the target a point on the cross-wires, not necessarily their point of intersection.

Aim-off.—The distance from the selected point to the vertical wire expressed in miles an hour.

Aim up, or down.—The distance from the selected point to the horizontal wire, expressed in yards.

Angle of aim-off.—The angle between the line of sight and the line of fire.

Angle of target movement.—The angle between the line of sight and the path of the target.

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Cross-wires.—The point of intersection of the vertical and horizontal wires of a telescope.

Expected point of impact (*E.P.I.*).—The point on the ground where the gunner expects his projectile to strike after allowance has been made for any inaccuracy of lay at the moment the projectile left the bore.

Firing interval.—The time from the moment the firer aligns his sights on to the target to the moment the projectile leaves the bore.

Fling.—The deflection of the projectile (expressed in yards or minutes of arc) due to the lateral velocity imparted to it by being fired from a moving platform.

Mechanical interval.—The time from the moment the firing mechanism is actuated to the moment the projectile leaves the bore.

Personal interval.—The time from the moment the firer aligns his sights on to the target, to the moment that he actuates the firing mechanism.

Selected point (*S.P.*).—The point in the field of a telescopic sight selected to be aligned on a target in order to apply a correction for deflection or elevation.

Time on aim.—The time from the moment the firer receives the order to fire, or the intimation that his gun is reloaded, to the moment he actuates the firing mechanism.

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CHAPTER I

BALLISTICS AND RANGE TABLES

1. *Objects of the chapter*

1. *Objects.*—The objects of this chapter are :—

i. To explain the theoretical factors which govern the flight of a shell.

ii. To explain the range tables supplied with the 3-pounder gun which show the application of those factors to tank armament.

2. Tank warfare conditions are such that shooting will necessarily be undertaken when the vehicle is moving.

The use of range tables is, therefore, not practicable.

The study of the range tables of the weapons with which the unit is equipped is, however, desirable in order that the characteristics of the latter may be fully understood.

2. *The rifled gun*

1. Gunnery is the science of directing a projectile from a gun so that it will strike a given object.

Tank gunnery is a branch of this science and deals with the use of the gun from a moving platform.

The gun serves two purposes. First, to confine the gases of a charge so as to allow them to exert pressure on the base of the projectile, and, secondly, to give the proper initial direction.

2. All modern guns are rifled and fire elongated projectiles. A gun is said to be rifled when a number of

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spiral grooves are cut along the interior of the bore, leaving raised ribs called "lands" between them. The lands cut into a comparatively soft driving band secured to the projectile. This gives the projectile a spin on leaving the muzzle. By this means the projectile is made to rotate rapidly about its longer axis and to travel nose first throughout its flight.

In the case of a bullet, the projectile is forced into and follows the grooves up the barrel.

The "twist" of rifling is described in terms of the distance, measured in calibres, in which the groove makes one complete circuit of the bore.

The twist of rifling in weapons used in the Royal Tank Corps is uniform.

3. *Muzzle velocity.*—When the charge of a gun is ignited, gas is generated and exerts a rapidly increasing pressure on the base of the projectile. When a certain pressure has been developed, the projectile starts to move and travels up the bore with continually increasing velocity until it leaves the gun with a certain muzzle velocity.

4. *Trajectory.*—The three main forces governing the flight of a projectile are :—

i. The force of the projection given by the explosion of the charge, tending to drive it along the line of departure.

ii. The resistance of the air opposing its progress and gradually decreasing its velocity.

iii. A force called gravity, explained below (para. 6).

5. *Resistance of the air.*—The air consists of a number of minute particles through which the projectile has to force its way. This produces a rapid loss of velocity ;

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for instance, the velocity of a shell from a 3-pounder gun, which at the muzzle is about 1,850 feet a second, is at 1,000 yards only about 1,250 feet a second.

The retardation due to the resistance of the air, varies according to the weight and diameter of the projectile, the shape of the head and base, and the steadiness of the projectile in flight.

Given similarity of shape and steadiness, if two projectiles of equal diameter, but of different weights, start with the same muzzle velocity, the heavier will lose its velocity more slowly and have the longer range, because it has the greater weight with which to overcome the resistance of the air. On the other hand, if two projectiles are of the same weight and of different sizes, the one with the smaller diameter will range further, because it presents less surface to the resistance of the air.

The velocity of the ·303″ bullet, which at the muzzle is about 2,440 feet a second, is at 1,000 yards about 1,800 feet a second.

6. *Gravity*.—The force of gravity is the natural attraction which causes every unsupported body to fall towards the centre of the earth. Moreover, the longer a body is exposed to its influence, the faster does it fall; thus a body falls :—

About 16 feet in the first second.
,, 48 ,, ,, second second.
,, 80 ,, ,, third second.

The result of these three main forces is that the path described by the projectile in flight is a curve; this curve is called the trajectory.

The projectile, in consequence of its high velocity and

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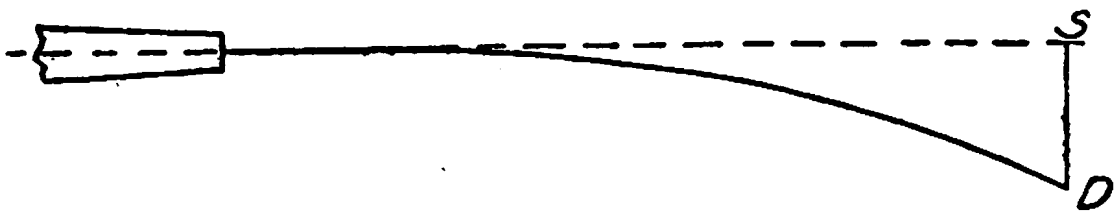
of the short time that gravity has had to act upon it, falls at first very little, but this fall, and consequently the curve, increases very rapidly with range.

The greatest height measured in feet attained by this trajectory above the line of sight is roughly four times the square of the time of flight measured in seconds.

$$H = 4T^2.$$

Thus, the 3-pounder shell when fired at 1,000 yards range attains a maximum height of 16 feet above the line of sight, as the time of flight for the range is 2 seconds.

Fig. 2.



7. *Laying for elevation.*—It is evident from what has been said that a projectile, fired from a gun at mark "S" (Fig. 2) will not hit that mark, but will strike some point at "D" below it.

To allow for the fall, it is necessary to point the axis of the gun as much above the object to be hit as the projectile would have fallen below it if the axis of the gun had been pointed straight at the mark.

This act of tilting the gun so as to allow for the curve of the trajectory is what is meant by the expression "laying for elevation."

The theory of giving elevation may be illustrated by reference to the flight of the 3-pounder projectile for the first 1,000 yards.

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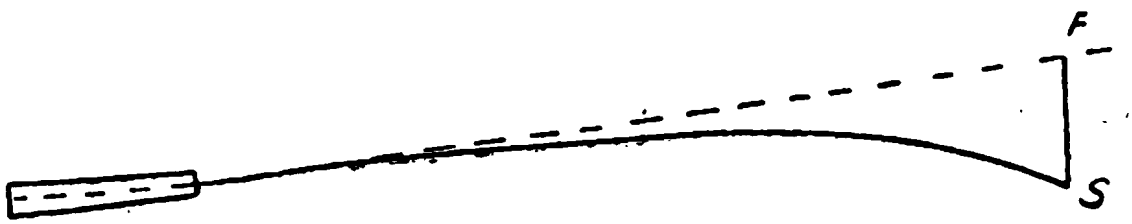
This shell falls about 16 feet below the line on which the shell leaves the bore in passing over the first 1,000 yards of its flight.

If an object (" S," Fig. 3) 1,000 yards from the muzzle is to be hit, the axis of the gun must be elevated so that if produced it will pass through a point " F " about 16 feet above " S."

Jump and droop both affect the line of departure and must be considered in connection with elevation.

The general theory of giving elevation can be demonstrated by means of a rifle placed on a tripod. If aim be

Fig. 3.



taken at a point on a blackboard about ten yards away, with the sights set at (say) 1,000 yards, and subsequently the bore be looked through without moving the rifle, it will be seen that the axis produced will be pointing considerably above the point aimed at.

From the above explanation it will be seen that the greater the range, the greater the elevation required.

When the performance of a gun is known, it can be given such elevation in degrees and minutes from the horizontal plane as will bring effective fire to bear on the target if the range is known and if the target is on the same level as the gun.

If the target is on a different level from the gun, the

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fact that the line of sight is laid on to the target in tank gunnery will compensate for this difference in level.

8. *Laying for direction.*—During its flight, various causes (fling, drift and the effect of wind) tend to make the projectile deviate to the left or right of its initial direction; consequently, if the line of sight is parallel to the axis of the gun, the projectile will deviate during its flight to the right or left of the line of sight.

To counteract such deviation it is necessary to set the line of sight at an angle to the axis of the gun in a horizontal direction. This angle is called " deflection."

If right deflection is given, the muzzle of the gun will move to the right in accordance with the amount of deflection given. Similarly, if the shell is required to go to the left, left deflection must be given.

By use of the data given in the range tables it is theoretically possible to set the deflection scale on the sights to compensate for *fling* and wind (*see* Sec. 4, 6 and 7). It is not, however, possible to do so in practice. *Drift* is, however, automatically compensated for (*see* para. 9, below).

9. *Explanation of drift.*—It has already been pointed out that the resistance of the air tends to retard the projectile. Owing to the fact that the projectile is spinning, the resistance of the air has a further effect, namely, to deflect the projectile in the same direction as the spin. With all service shell, this spin or rotation is right-handed; with small-arm projectiles it is left-handed, and consequently all shell have a tendency to be deflected towards the right and all bullets to the left in the course of their flight.

This deflection is called " *drift.*" As this rotation is

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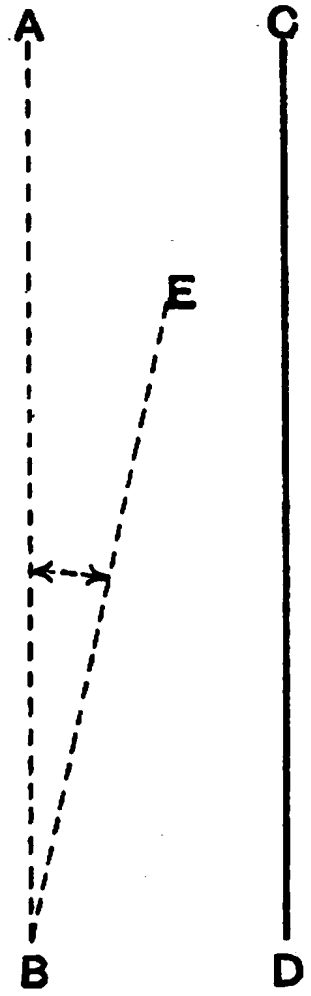
definite, and diminishes very slightly during the flight of a shell, the amount of *drift* can be determined approximately for each nature of gun, by actual experiment, and compensation made for it. In tank gunnery such compensation takes the form of permanent inclination of the sight to the axis of the trunnions.

By this means the line of departure is pointed to the left of the line of sight and *drift* is thus allowed for; the system, although not entirely correct theoretically at all angles of elevation, is sufficiently accurate for practical purposes.

This inclination of the axis of sight can be demonstrated as follows :—

Using a 3-pounder gun (Fig. 4).—With sights set at zero both for elevation and deflection, elevate the gun and lay the cross-wires on any convenient point (A); the line of sight (BA) and the axis of the gun (DC) will be parallel. Rotate the range drum by its handwheel; the cross-wires (line of sight (BE)) will move horizontally towards the gun. The angle ABE will be the angle due to *drift* for the range shown on the range drum.

Fig. 4.



3. *Interior ballistics*

1. The chief forces acting on the shell in the bore are :—
   i. *The force of projection*—that is, the pressure on the base of the shell caused by the gases generated when the charge is ignited.

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ii. *The force of rotation*—that is, the pressure of the driving edges of the rifling on the driving band. This causes the shell to rotate.

2. The following are some of the conditions which affect the pressure on the base of the shell :—

i. The amount of gas generated, depending upon the weight and nature of the charge.
ii. The rate at which the gas is generated, depending upon the shape, size, and nature of the propellant used.
iii. The heat to which the gases are raised. The greater the heat developed the more the gases will be expanded, and the greater the pressure.
iv. The temperature of the charge before firing.
v. Air spacing.

3. The velocity attained by a shell at the muzzle of a gun is due to the pressure of gas during its passage through the bore. The more gradually velocity is imparted to the shell the less will be the strain upon it and the gun. The object sought is to distribute as far as possible the pressure over the whole length of the bore, and to obtain the maximum work from a given charge without undue strain to the gun or shell.

The charge is designed to produce a muzzle velocity to meet requirements.

4. The comparatively high velocities required with modern guns can only be obtained by using large charges giving high pressures. If a quick-burning propellant be used, high initial pressures will result, necessitating great strength at the breech. High initial pressures due to the heat generated cause much wear and erosion

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of the bore, and consequently shorten the life of a gun. This is partly overcome by using a slow-burning propellant.

Theoretically, to get the full benefit of a slow-burning charge, a very long gun is necessary, so that the propellant may be entirely consumed before the shell leaves the bore. Practically, the length of the gun is limited by considerations of weight, handiness, and strength of material.

5. The muzzle velocity, and consequently the range obtained from any particular elevation, will vary with the charge used.

6. *Air spacing.*—In modern guns the capacity of the chamber is greater than is required to contain the charge so as to allow for air spacing.

If the charge is given more space in which to burn, the maximum pressure in the gun is decreased and with it the muzzle velocity; but the pressure decreases far more quickly than the velocity.

Therefore, by increasing the air spacing the charges to be used may be larger, and higher muzzle velocities can be obtained without increasing the maximum pressure.

7. *Driving bands.*—The driving band is an important part of the shell. It provides the means by which rotation is imparted by the rifling, and a seal for the propellant gases.

Friction between the driving band and the rifling has a retarding effect on the shell. Different designs of driving bands give rise to different resistances, and hence alteration in muzzle velocity.

These two causes of alteration of muzzle velocity can

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only be dealt with by calibration of each gun with each driving band in use, unless satisfactory information regarding comparative velocities is available.

8. *Coppering and nickelling.*—Coppering or nickelling, which is the deposit of copper or nickel on the inside of the bore from the driving band, has the effect of retarding the shell and causing a decrease in muzzle velocity.

9. The various forces which act on a shell inside the bore and their effect on its flight are calculated and compensated for as far as possible before the gun is issued for service.

4. *Exterior ballistics*

1. It has been shown in Sec. 2, that the two main forces acting on a projectile in flight are the resistance of the air and gravity.

The amount of retardation of a projectile in flight depends upon its weight, diameter, shape of head, steadiness in flight, and the density of the air.

The variation columns in the range table provide figures for correction to elevation due to alteration of any of these conditions from those for which the range table was compiled. The conditions of tank gunnery, however, render it impossible to make use of these corrections in practice, and the short ranges at which tanks normally engage targets make it unnecessary to do so.

2. The projectile, having left the bore at a definite muzzle velocity, is affected in flight by the following forces :—

i. The air.
ii. Gravity.
iii. Fling.

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3. The range tables and range drums are prepared for firing under *normal conditions*.

Air density, however, varies with :—

i. Alteration in temperature.
ii. Alteration in barometer.

4. *Air*.—The normal temperature of air is 60 degrees Fahrenheit. If the temperature rises the air expands and becomes less dense. The resistance it offers, therefore, is less and the projectile ranges further.

5. *Barometer*.—A rise in the barometer indicates that the air is denser and will offer more resistance, causing the projectile to range short.

6. *Wind*.—A following wind causes increased ranging of the shell ; a side wind blows the projectile off for direction.

7. *Fling*.—A projectile fired broadside or partly broadside, from a moving vehicle is flung aside from its course in the direction of the movement of the vehicle. The amount of *fling* depends on the speed and direction of the tank and the muzzle velocity.

Range tables give the necessary theoretical data for all these factors together with the corrections for day conditions, etc. (But *see* Secs. **1**, 2.)

8. There are, however, other factors which affect the range and line, but the necessary allowances are made in the setting up of the sights which obviate the necessity for corrections to be made under conditions of shooting in a tank.

These are :—

i. *Jump*.—Caused by up or down movement of the gun, due to the departure of the projectile, which varies with the elevation.

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ii. *Droop.*—Caused by the bending of the front portion of the piece (partly due to manufacture and partly due to the unsupported weight at the muzzle end).

iii. *Variations in muzzle velocity.*—(*See* Sec. 5.)

9. *Explanation of mean point of impact.*—Even when all conditions are normal a succession of rounds fired from a gun, laid each time at the same elevation and line, will not fall all in the same spot owing to certain unavoidable sources of inaccuracy. All the rounds will fall within a rectangular area the length of which is the 100 per cent length zone, and the breadth the 100 per cent breadth zone. The fall of the rounds will be thickest at the centre, the centre of the rectangle being the "*Mean point of impact*" (*M.P.I.*).

The 90 per cent zones are given in range tables from which can be found the probable percentage of hits in a given area.

10. In the case of the Vickers machine gun the conditions are somewhat different, and the following terms are used:—

i. *Cone of fire.*—The pattern in the air formed by the highest and lowest shots of a burst of fire. (This can be found by firing through a vertical target.)

ii. *Beaten zone.*—The area beaten by the cone of fire on the ground.

iii. *Height zone.*—The vertical area beaten by the zone.

Machine guns are sighted so as to place the centre of the beaten zone on the target.

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5. *Range tables*

Range tables represent the ordinary performance of a gun with standard ammunition under normal conditions, and with angle of sight at " zero." The figures are based on actual practice, but owing to the difference in the behaviour of individual guns, and the limit of accuracy of experimental data, they can at present only be considered as a guide.

In order to compile these tables, series of rounds are fired at various elevations for range and accuracy. The gun is placed on a firm platform and the series are fired through velocity screens, by means of which the muzzle velocity is measured. The screens also provide a means of measuring the jump for the particular gun under test, so that the angle of departure can be calculated. The practice ground is pegged out in yards both down and across the line of fire, so that the range of each round and its deviation can be determined quickly and accurately.

The process is repeated for other elevations and the results, together with the actual meteorological conditions at the time of the trial, are carefully analysed. The figures for the intermediate elevations are interpolated, and all are corrected for atmospheric and other conditions, and for the muzzle velocity for which the range table is to be compiled. The main consideration which governs the selection of this muzzle velocity is that it should be as nearly as possible equal to the mean muzzle velocity produced by a gun during the greater part of its life under normal conditions in the field.

The information thus obtained, together with the results of other trials, is tabulated in the main body of the range table.

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6. *Information obtained from range tables*

The following is an explanation of the information contained in the main body of the range table, and should be studied in conjunction with the range table issued for the 3-pounder gun :—

i. *Time of flight.*—This gives the time of flight in seconds.

ii. 90 *per cent probability zones.*—These columns give the length and breadth of the area in which 90 per cent of rounds should fall.

iii. *Angle sub-tended by a target* 10 *feet wide.*—This information is useful for calculations of theoretical "*aim-off.*" (*See* Sec. 9, 1.)

iv. *Alteration of elevation corresponding to* 100 *yards variation in range.*—This information is included for calculation of tangent elevation when the muzzle velocity is abnormal.

v. *Tangent elevation.*—The tangent elevation in degrees and minutes is shown for every hundred yards up to the limit of range of the gun.

vi. *Range.*—Extreme ranges are given for calculation of safety areas and for information in the event of a tank gunner being called upon to fulfil an abnormal role.

vii. *Slope of descent, and angle of descent.*—This information is included for calculation of angles of impact.

viii. *Permissible error in over-estimation of range to hit a target* 10 *feet high.*—This information is useful to the tank gunner in order that he may realize what effect an error in judging range

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will cause, and how often it is necessary to alter the range in practice.

ix. *Deflection correction for travel of tank at* 10 *m.p.h. at right angles to line of fire.*—The information in this column should be known by all tank gunners. With the help of the footnote marked " * " any theoretical "*aim-off*" can be calculated.

x. *Remaining velocity.*—This information is required for calculation of penetration.

xi. *Deflection correction for travel of target at* 10 *m.p.h. at right angles to the line of fire.*—The remarks in sub-para. ix, above, apply equally to this column.

xii. *Penetration of armour plate.*—This information is of tactical value in tank combat.

CHAPTER II

TANK GUNNERY

7. *Task of the tank gunner*

1. *General.*—The equipment, for example, of coastal and anti-aircraft artillery, permits of the engagement of moving targets, but, on land, firing on the move is peculiar to the armoured fighting vehicle. A number of factors inapplicable to any other branch of gunnery on land have therefore to be taken into account. What these factors are, and how the training of the tank gunner is designed to deal with them, is explained in this chapter.

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Similar factors arise in naval gunnery, where they are solved largely by instrumental means. Owing to the characteristics of the vehicle such solution is applicable to the problems of tank gunnery only to a limited degree.

It is, therefore, upon the training of the individual gunner that effective fire, and consequently success in war, depends.

2. *Tank armament.*—The armament of a tank consists of :—

i. Single shot weapons (including large-calibre machine-guns when used as single-shot weapons) intended primarily for use against armoured fighting vehicles or other objectives impervious to ·303-inch fire.

ii. Automatic weapons for use against personnel in the open, including crews of anti-tank weapons and armoured fighting vehicles for blinding effect.

These weapons may be controlled by :—

(*a*) Gears.
(*b*) Direct holding by the gunner.
(*c*) A combination of both.

3. *Object of the tank gunner.*—The object of the gunner is :—

i. To hit quickly with the first shot or burst of machine-gun fire.

ii. If this fails, to profit by the information obtained from this and attempt to hit with the next.

iii. To keep on hitting although the conditions may alter.

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Rapidity in obtaining effective fire is vital, for in the majority of tank engagements the target is endeavouring to hit back. Unless it is first disabled, it will hit back or disappear.

8. *Training the tank gunner*

1. *Characteristics of the gunner.*—An efficient gunner must possess qualities of judgment, determination, and decision, and mental and manual dexterity which can only be produced by training. It is therefore necessary that every man should be thoroughly trained in all the earlier stages of tank gunnery. The men who show particular aptitude should be selected for further training and practice in firing shell and small-arm ammunition at longer ranges and under battle conditions, so as to obtain most value from the limited amount of ammunition available, and to build up a reserve of skilled gunners.

2. *The factors in training.*—In order to develop the full fire power of an armoured fighting vehicle the commander and gunners must be able to carry out proficiently all the following operations :—

i. *Care and adjustment of the weapon.*—In order to obtain the best results from any weapon, it must always be kept in perfect mechanical condition and adjustment, as laid down in Part II of this manual.

ii. *Recognition of the target.*—The targets that will be engaged by a tank will frequently be small, and will be rendered as inconspicuous as possible by the enemy. The gunner will also

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be handicapped by having to look through small apertures and from a strained position, with a very limited field of view. His eyes and powers of observation must therefore be trained to a very high degree to enable him to pick out his targets either by description or by his own initiative.

iii. *Choice of weapon.*—This depends on :—

(*a*) The nature of the target.

(*b*) The characteristics of the armament of the tank.

(*c*) The effect it is desired to produce.

To enable intelligent decisions to be made on these points, personnel must be given previous training in the principles of interior and exterior ballistics and the effectiveness of various types of service ammunition against armour plate.

iv. *Estimation of range.*—In the absence of range-finding instruments in a tank, the range must be estimated as accurately as possible by the appearance of the target in the sights or to the naked eye, and the aspect of the intervening ground.

The importance of the accurate judging of distance cannot be over-estimated, for without it, not only is it impossible to hit the target with the first round, but the round may even escape observation, which will delay the attainment of effective fire.

v. *Estimation of allowance for movement of tank and target.*—The gunner must be trained to make

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estimates of the conditions, perform the necessary simple calculation in his head, and choose the correct *selected point* for the problem almost instinctively.

An elementary knowledge of the principles of gunnery involved in problems of moving tanks and targets is necessary, as the broad principles hold good in every case. In addition, the gunner must have a thorough knowledge, ingrained by constant practice, of the methods employed to deal with the problems of his own particular equipment.

vi. *Overcoming oscillation.*—This is the main difficulty of tank gunnery, and involves the temporary alignment of the sights on the target and the discharge of the weapon whilst in that position, despite the motion of the machine. This requires mental and manual dexterity on the part of the gunner, only attainable by constant practice.

vii. *Observation and correction of fire.*—Every round of shell or burst of machine-gun fire must be observed if possible, a cause assigned if it was a miss, and a suitable correction applied to the next round.

9. *Allowance for movement of tank and target*

1. *Target movement.*—During the time of flight, the target moves a distance determined by the speed at which it is travelling. When the projectile is fired, there will be a period during which both projectile and target are moving along their respective paths. If,

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however, the gun has been correctly sighted at the moment of firing, the projectile and target will arrive simultaneously at the same point, and a hit will result.

The *angle of aim-off* can be calculated mathematically when the *time of flight*, the distance moved by the target and the *angle of target movement* are known.

Such calculations show that at the ranges at which moving tanks engage their enemy, the *angle of aim-off* remains practically constant for any given target speed.

It has been found that, for the 3-pounder shell and ·303-inch Mark VII ammunition, three times the speed of the target (in miles an hour) will give the necessary *angle of aim-off* for enemy movement in minutes of angular measurement when the *angle of target movement* is 90 degrees.

$$3S = \text{angle in minutes.}$$

where S = speed of target in m.p.h.

e.g. at 5 m.p.h. the angle is 15 minutes.

When the *angle of target movement* is 30 degrees the *angle of aim-off* is half this, *e.g.* 15 minutes at 10 m.p.h.

When the *angle of target movement* is 45 degrees the *aim-off* is three-quarters.

When the *angle of target movement* is 60 degrees or over, the full *aim-off* will be taken.

2. *Allowance for fling.*—*Fling* is at its maximum when the path of the gun platform makes a right-angle (90°) with the line of sight, and decreases as this angle becomes less. The *angle of aim-off* necessary to counteract *fling* at any given speed can be calculated mathematically.

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It has been found by calculation that for the 3-pounder shell and ·303-inch Mark VII ammunition, the *angles of aim-off* required to compensate for *target movement* and *fling* are practically identical for any given speed of platform and target, and therefore the allowance for *fling* can be made in a similar manner to that for target movement.

3. *The graticulation of the telescope as an aid to the application of aim-off.*—The Aldis No. 22A telescope is constructed with the horizontal wire, partly thick and partly thin. If the junction of the thick and thin portions of the horizontal wire be taken as the *selected point*, the angle of aim-off is 45 minutes. (*See* Fig. 5, page 34.)

It has been shown that the *angle of aim-off for* 15 m.p.h., whether due to *fling* or *target movement* is 45 *minutes;* consequently the junction of the thick and thin portions must be the *selected point* for a broadside speed of 15 m.p.h.

It is, therefore, simple to sub-divide by eye this section of the cross-wire into three equal portions, each portion representing a broadside speed of 5 m.p.h., or angle of 15 minutes. (*See* Fig. 6.)

Consequently the *selected point* for *aim-off* for *fling* due to broadside speed of own tank at 5, 10, or 15 m.p.h., or for allowance of broadside target movement at same speeds is respectively 5, 10, or 15 m.p.h. *selected point.*

These will be known respectively as 5, 10, or 15, and *right* (or *left*) of the cross-wires.

4. *Practical method of aiming-off for fling :—*

i. It will now be obvious that when the gunner is firing at 12 o'clock or 6 o'clock the *fling* is nil, and the *selected point* is the cross-wires.

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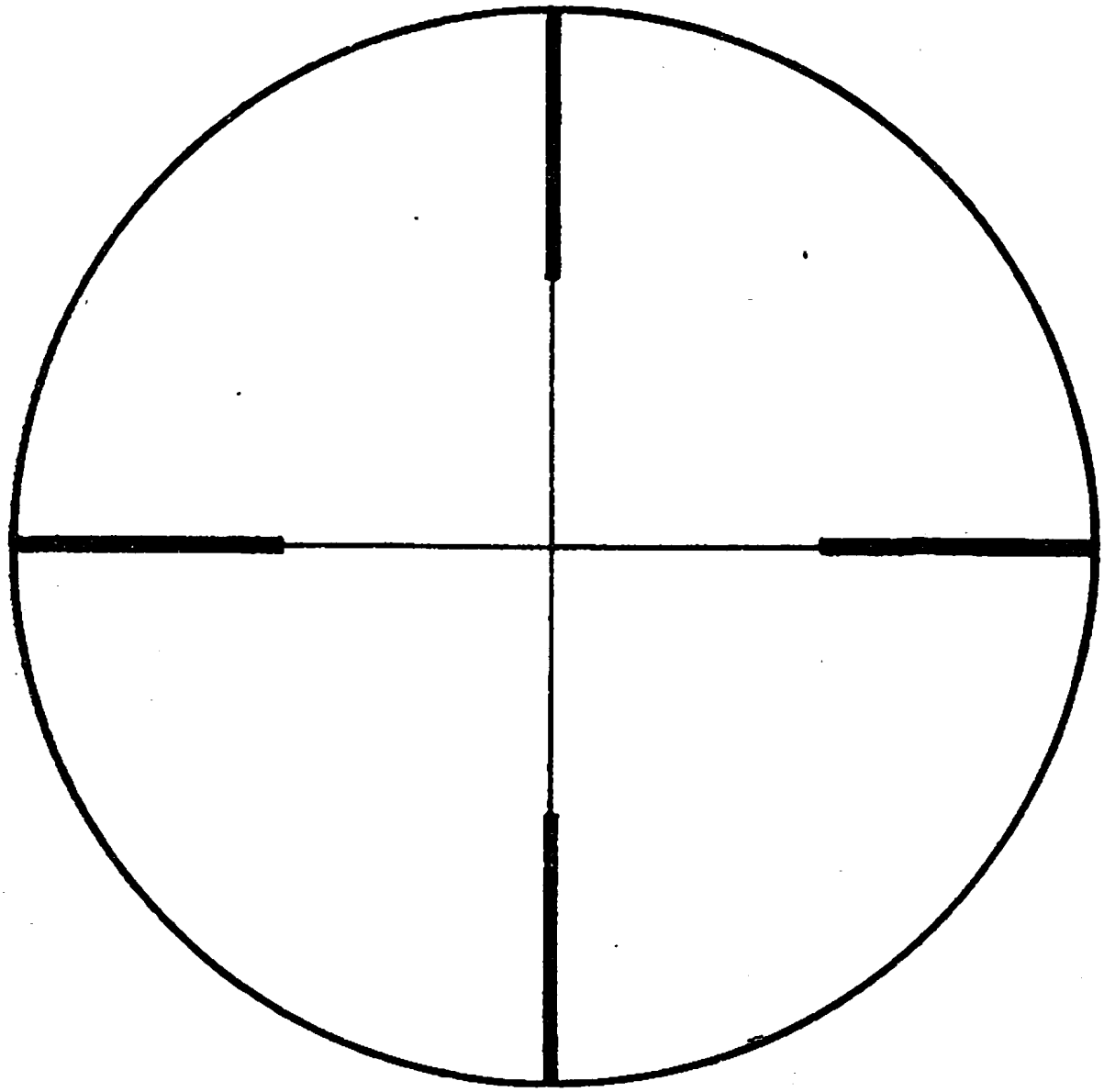
ii. When he is firing on the right side of the tank the *selected point* will be to the left of the cross-wires and *vice versa*.

Fig. 5.



iii. For 2, 3, 4 or 8, 9 or 10 o'clock the *selected point* will be 5, 10 or 15 respectively for own speed of 5, 10 or 15 m.p.h.

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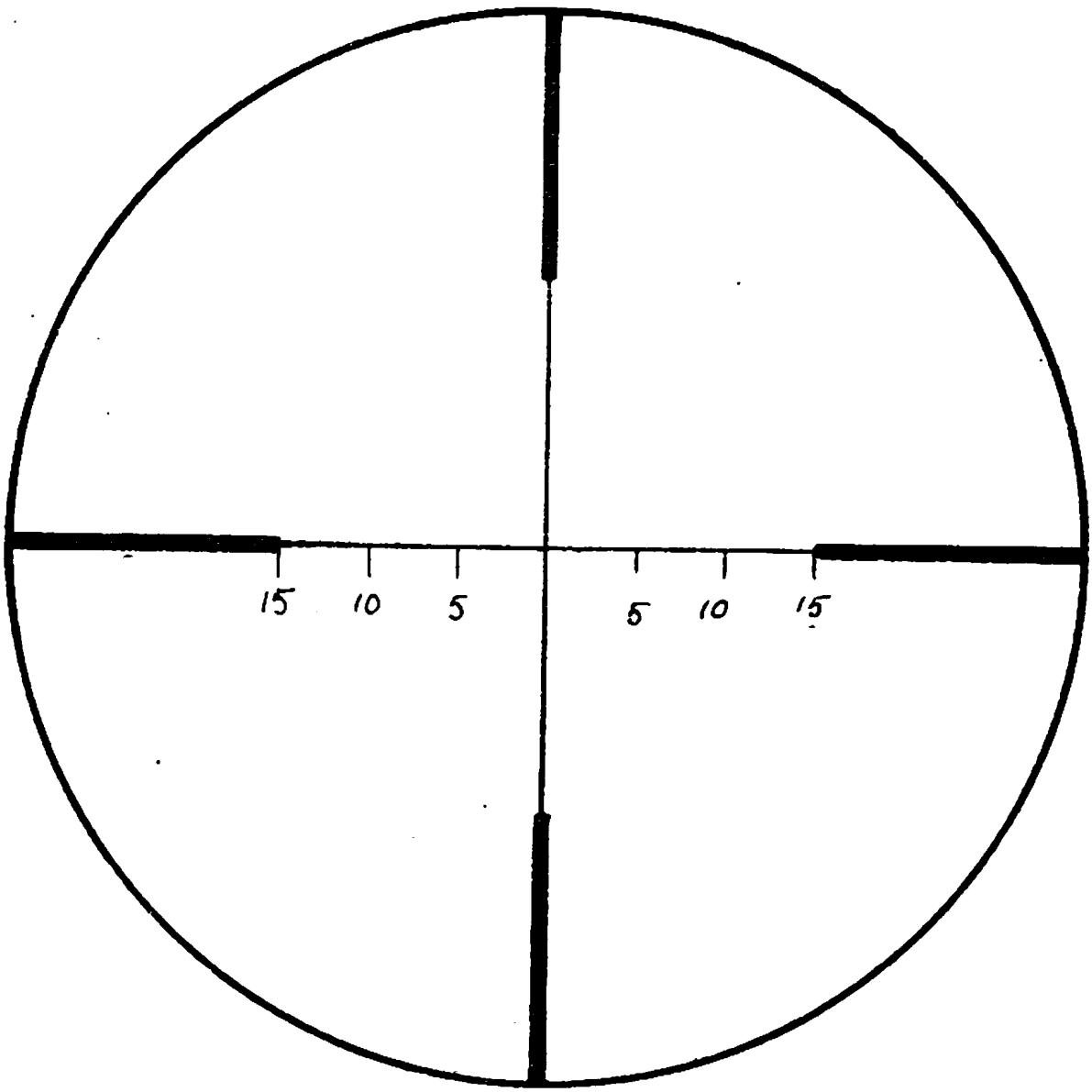
iv. For 11, 1, 5 and 7 o'clock the *selected point* will be half the above, *e.g.* for a speed of 10 m.p.h. it will be 5.

Fig. 6.



5. *Practical method of aiming-off for target speed* :—

i. If the target movement is directly along the line of sight, no *aim-off* is necessary.

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ii. If target movement is directly to *left* (or *right*) of the line of sight, a full aim-off will be necessary, *e.g.* for target speed of 5 m.p.h., it will be the 5 *selected point* and so on.

iii. When the *angle of target movement* is judged to be 30 degrees, half the estimated speed will be allowed for, *e.g.* for a speed of 10 m.p.h., the 5 *selected point* will be taken. Similarly for 45 degrees, three-quarters will be taken.

iv. If the target is moving right the *selected point* will be to the left of the cross-wires and *vice versa*.

6. *Combined aim-off.*—The gunner must always be taught to solve each of the problems of *aim-off* for *fling* and *target speed* separately, before combining them in an *aim-off*.

Fire orders are a guide to the gunner in calculating *aim-off* for *fling*. For example, if he gets the order "Driver 15; 3-pounder, 9 o'clock," he knows that the *selected point* to correct for *fling* should be 15 and *right* of the cross-wires.

If he is then given a target moving right at 10 m.p.h., the *selected point* to correct for *target movement* will be 10 and *left* of the cross-wires.

Therefore, 10 *left* from 15 *right* gives the correct *selected point* for the shot, *i.e.* 5 and *right* of the cross-wires.

Similarly: "Driver 10; 3-pounder, 1 o'clock," gives the gunner *selected point* 5 and *left* of the cross-wires as his correction for *fling*. He then is given a target moving left at an angle of 45 degrees at 15 m.p.h. (as he estimates).

This gives him 10 and *right* of the cross-wires as his correction for target movement.

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The correct *selected point* will therefore be 5 and *right* of the cross-wires.

NOTE.—The fire order is only a guide to *aim-off* for *firing* for the first shot. In any case the gunner must make his own estimate of the speed of his own tank at the moment of firing, since the driver may not always be able to drive at the speed ordered.

7. *Aiming-off, using the battle-sight of the Mk. I Vickers machine gun.*—The principles of aiming-off with this sight are similar to those laid down for the 3-pounder.

The sights give little assistance to aiming-off as compared with the graticule of a telescope, but as a guide, if the wings of the foresight protector are laid on the target instead of the blade of the foresight, this is equivalent to an *aim-off* of 10 m.p.h.

8 *Aiming up or down.*—The thin portion of the vertical wire can be used for aiming up or down, when it is desired to avoid constant alteration of the range drum by small amounts. (*See* Sec. **11**, 4 and 6.)

10. *Oscillation*

1. *Causes of oscillation.*—The oscillation at any given moment depends on :—

i. *Nature of the ground.*—This affects the motion of the tank by :—

(*a*) The inequalities of the surface.
(*b*) The hardness and softness of the surface.

ii. *The design of the machine.*—This affects the degree of oscillation. The longer and wider the machine, the steadier it will be ; in machines of

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similar size the type of suspension is an important factor.

But although improved methods of suspension may give a more even motion, no vehicle can travel quite smoothly over rough ground.

iii. *Alteration of course.*—The smallest alteration of course upsets the gunner because of the general pitching motion caused by the operation of the steering clutches, and also because of the traverse necessary to regain his aim, and the necessity for a fresh *aim-off* estimation.

iv. *Constant speed.*—The motion rapidly becomes more violent with an increase of speed. Every acceleration of the engine causes an upward pitch of the tank, and every deceleration a downward pitch. It follows that the driver should keep his foot steady on the accelerator, or drive on the hand throttle if provided. Variations in the speed also necessitate alterations to aim-off.

v. *Gear changing.*—Produces violent pitching of the machine, unless very smoothly made.

vi. *Obstacles.*—Inevitably disturb the gunner, but if taken skilfully only momentarily interrupt the fire.

General.—The driver must, therefore, give every assistance to the gunner. He should time his turns or changes of gear so that they take place immediately after the gun has been fired, as the gunner will not then be *steadying on.*

2. *Effects of oscillation.*—Oscillation causes difficulty in laying and also in ensuring that the *selected point* is on the target at the moment of discharge.

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3. *Laying* :—

i. The motion of the tank consists of periods of major oscillations, with intervals of minor oscillations, when the motion is comparatively steady. A skilled gunner will not attempt to fire during periods of major oscillation.

To fire during a period of minor oscillation he must become thoroughly accustomed to the motion of the tank under every condition, so that he instinctively knows when a lull is coming, and when it is advisable to attempt to fire. This instinctive anticipation of the movement of the vehicle is known as *tank sense*.

ii. To take advantage of the brief opportunities to fire, the gunner's muscles must be so trained to the use of the elevating and traversing wheels, or other method of controlling the weapon, that every movement of the tank is automatically counteracted without conscious thought, so that the *selected point* is always kept near the target, and is accurately aligned on it at the first opportunity. To obtain this instinctive co-operation of eye, brain and muscle, constant practice in the manipulation of the weapon is necessary, both on training apparatus and in the moving vehicle.

iii. Under very bad conditions of oscillation it may be impossible even for an expert gunner to train his sights on the target and fire. In these circumstances the gunner watches his wires rising and falling across the target and attempts to anticipate the movement by firing before the cross-wires actually cross the target, so judging the action that by the time the shell leaves the bore the *selected point* is actually on the target. This method is known as *snapshooting*. It is very

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difficult to put into practice with accuracy, and should only be resorted to when it is quite impossible to steady on. The gun should be fired with the wires falling, as any delay will result in the round falling short, when it may ricochet on to the target, and will at least give observation.

iv. *Determination.*—Unless the gunner strains every nerve and muscle to overcome the oscillation of the vehicle, no amount of training and practice will make him a really good shot.

4. *Firing.*—In spite of every effort on the part of the gunner the sights can only be aligned on the target for very brief intervals of time, and during these intervals the projectile must leave the bore.

It is essential to rapid and accurate shooting that the firing interval should be reduced to the smallest possible amount, for two reasons :—

i. If the gunner does not fire immediately his sights come on, he may miss the brief opportunity afforded by the lull in the oscillation. This will reduce the rate of fire, and will add to the fatigue of the gunner, as he will have to maintain the effort of trying to get on to the target for a longer period.

ii. If the gunner starts to fire with the sights aligned, but the sights are moved off before the projectile leaves the bore, a miss will result.

A study of the series of events that must precede the discharge of a projectile will show that the firing interval can be reduced. These events are :—

(1) The eye tells the brain that the sights are in the correct relation to the target.

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(2) The brain DECIDES to fire.
(3) An impulse is sent along the nerves to actuate the muscles necessary to move the firing mechanism.
(4) The muscles move the firing handle the required distance.
(5) This movement is transmitted to the trigger or sear of the firing mechanism.
(6) The firing-pin travels on to the cap.
(7) The cap composition ignites and in turn ignites the charge.
(8) The projectile moves along and out of the bore.

The first four of these events take place within the gunner himself, and the aggregate time taken is called the *personal interval.*

The remaining four take place within the mounting and piece, and the time taken is called the *mechanical interval.*

The *mechanical interval* can only be reduced by alteration in design, but the *personal interval* varies widely in individuals, and can always be reduced by training :—

(1) By constant practice the nerves and muscles concerned learn to work smoothly together, and the time occupied by their train of operations is much shortened.
(2) By learning to make the DECISION to fire the moment the *selected point* is on the target, without hesitation or delay.
(3) By improvement in the physical fitness of the gunner.

DECISION is the key-word of correct timing in shooting.

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5. *Continuation of fire.*—Once fire has been opened it must be kept up at the maximum rate until the target is destroyed or lost to sight. The rate of fire depends on :—

i. The gunner's time on aim.
ii. The skill of the loader.
iii. The placing of the ammunition.
iv. The oscillation of the tank at the time.

Time on aim depends on :—

DETERMINATION to overcome the oscillation of the vehicle and to align the sights on the target;

DECISION to fire the first time this object is achieved.

The gunner must be instinctively aware of the progress of the loader, so that he may be in a position to fire the moment he is notified that loading is complete.

Skill of the loader.—The loader must always have a fresh round ready so that the gunner misses no favourable opportunity to fire.

Placing of the ammunition.—Owing to the large number of rounds packed into the small space of a tank, some of them are of necessity less accessible than others. The loader must take advantage of every lull in the firing to refill his more accessible racks.

Oscillation.—Reduces the rate of fire by increasing the gunner's time on aim and by making the loader's task more difficult.

6. *Machine-gun fire.*—The above considerations refer primarily to the handling of a single-shot weapon, and more especially one firing a shell; but the problems affecting fire from an automatic weapon are similar. There is, however, the additional requirement that the gunner must try to keep continually on the target during

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the whole burst of fire, and not only for the relatively short time required to fire a single shot.

It has been shown that it is impossible for the sights to be kept continually in perfect alignment with the target under the conditions of oscillation in a tank; but it is possible for a skilled gunner to keep them nearly so.

It must be the aim of a machine gunner to keep his sights sufficiently near the target so that some part of the beaten zone covers the target, and should the gun be deflected too far from the target by the motion of the tank, to bring it back again without ceasing fire.

This is possible during all periods of minor oscillation, and fire need only be stopped when the gun is unduly deflected by major oscillations.

The maximum fire effect of the machine gun in a given time is developed by continuous fire. Any attempt to fire in short bursts sacrifices fire effect. The moral effect of continuous fire is of great value in reducing the accuracy of hostile fire.

The tank can carry a considerable number of rounds of ammunition, and its engagements, though intense, will usually be short. Any necessary economy of ammunition should, therefore, be effected by the control of fire and the careful selection of targets at suitable ranges, rather than by the reduction of the volume of fire once it has been opened.

11. *Observation and correction of fire*

1. *Observation.*—The fall of each shot or burst of fire must be observed by the gunner in order to enable him to keep on the target if a hit is obtained, or to make the necessary corrections to hit it subsequently.

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This requires training and experience, for the 3-pounder shell, being small, only gives a small detonation on impact, and machine-gun bullets only show up clearly on favourable ground.

With flat trajectory weapons on flat country, rounds that are only slightly out for elevation will strike the ground several hundred yards away from the target. It is then difficult to estimate the extent of their error, or they may escape observation altogether.

Proficiency in observation can be gained by :—

i. Knowledge of the time of flight. This tells the gunner when to expect his projectile to arrive, and enables him to distinguish it from those of other tanks.

ii. Knowledge of the appearance of shell bursts and bullet splashes.

iii. Practice in the observation of fire in order to obtain the necessary quickness of perception. This practice can be obtained on the miniature range and by watching others shoot, as well as by actual shooting experience in a tank.

The use of tracer ammunition greatly facilitates the observation of fire. Observation of the trace itself is, however, deceptive. The trace should rather be regarded as a means of guiding the eye to the point of impact of the projectile. This particularly applies to the trace of ·303-inch tracer ammunition, which frequently burns out before the bullet strikes.

2. *Correction of fire.*—Corrections are made for :—

i. Errors in estimation of range.

ii. Errors in estimation of *aim-off*.

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iii. Alteration of range since last shot.
iv. Alterations of the factors governing *aim-off* since last shot.

Corrections are made in two stages :—

Estimation of error observed.
Application of suitable correction for next round.

3. *Correction by use of the expected point of impact* (*E.P.I.*).—It will frequently occur that owing to some sudden movement of the vehicle, or misjudgment on the part of the gunner, the shell will leave the bore with the *selected point* on some point other than the target.

Although in these cases the gunner does not expect to see his shell strike the target, he must still observe it carefully, for he can obtain from its observation valuable information to correct his estimation for *aim-off*, so that when he does discharge an accurately laid round it will obtain a hit.

To obtain this information, estimates of the amount of error must be made, not with reference to the target, but to the E.P.I. on the ground.

This is taught the gunner by making him declare his point of aim from the earliest stages of miniature range training.

4. *Correction for range :—*

i. *When there is high ground behind the target.*—When the ground rises steeply behind the target this problem is comparatively simple, for the apparent distance of the point of impact from the E.P.I. can be measured up or down by using the vertical wire as a scale, and the next round aimed a similar distance

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above or below, or the range drum can be suitably adjusted.

With the 3-pounder Mk. II gun, 100 yards alteration of range corresponds to 9 minutes of elevation, with sufficient accuracy up to 1,500 yards.

In the Aldis No. 22A Telescope, 9 minutes is represented by one-fifth the distance from the cross-wires to the commencement of the thick portion. As an example, the gunner may either aim up three-fifths of the thin portion of his vertical wire or put up his range drum by 300 yards.

ii. *On level ground.*—When the country is compartively level it is not possible to use the vertical wire to measure errors of elevation, because the point of impact is always seen approximately in the same horizontal plane, whether the shell falls short or over the target.

As it is difficult to estimate accurately the distance the shell strikes beyond or short of the target, corrections must be bold ; usually not less than 300 yards.

iii. *Corrections by use of the E.P.I.*—Suppose the gun was fired with the cross-wires in the position as shown in Fig. 7. If the ground behind were flat, the shell would be expected to strike 200 yards beyond the target.

If the shell actually appeared to burst this distance behind the target, no correction of range would be needed for the next round.

If it actually burst, say, 100 yards SHORT OF THE TARGET, a correction of 300 yards would be necessary.

If it burst obviously beyond the E.P.I., a bold MINUS correction of 300 yards would be necessary.

If in subsequent rounds only a small correction is

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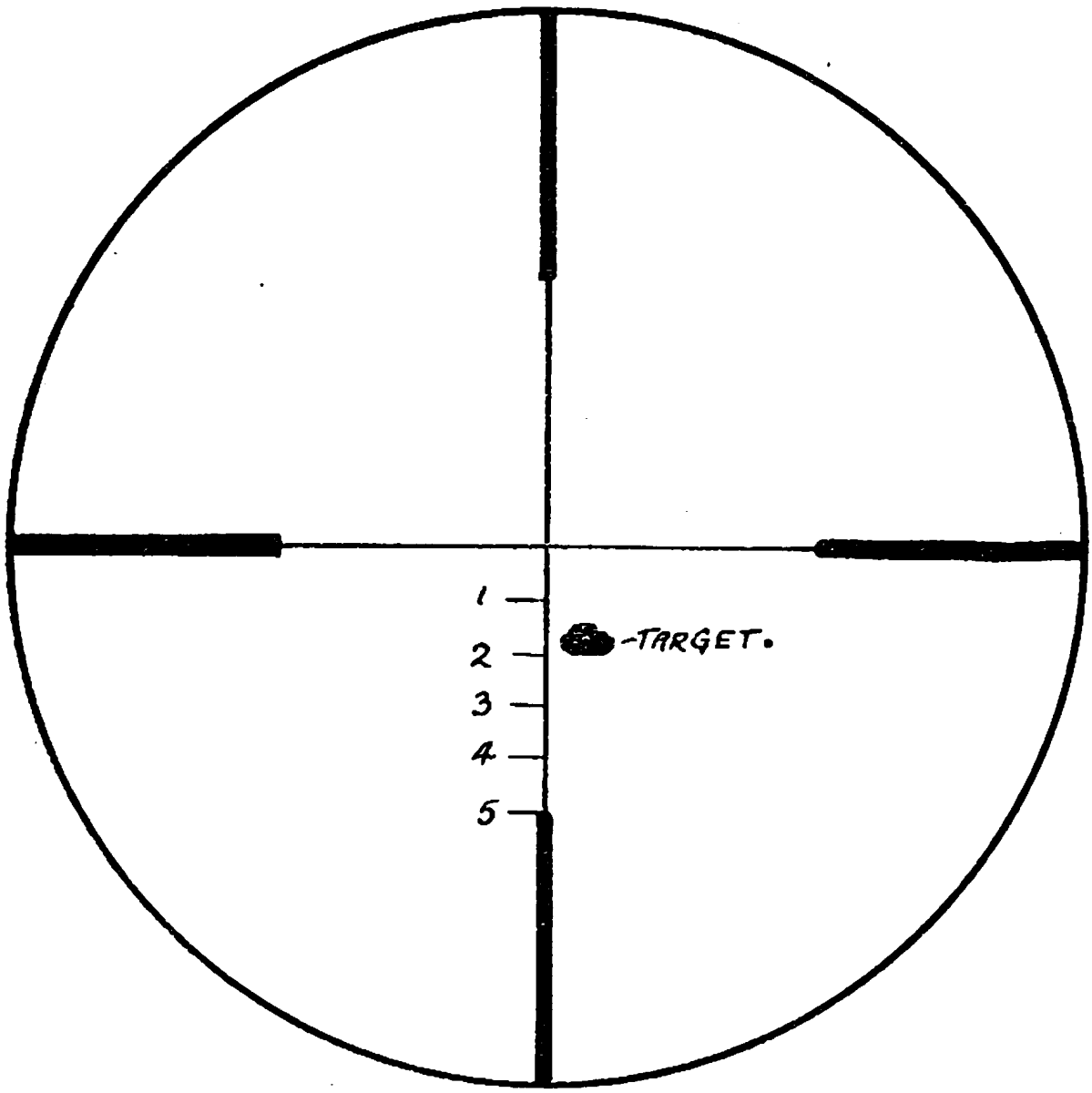
found necessary, this should be applied by aiming up or down.

5. *Correction for line.*—Provided that the round is

Fig. 7.



approximately accurate for elevation, the horizontal wire may be used as a scale to measure the apparent distance from the E.P.I. of the actual burst. Thus in

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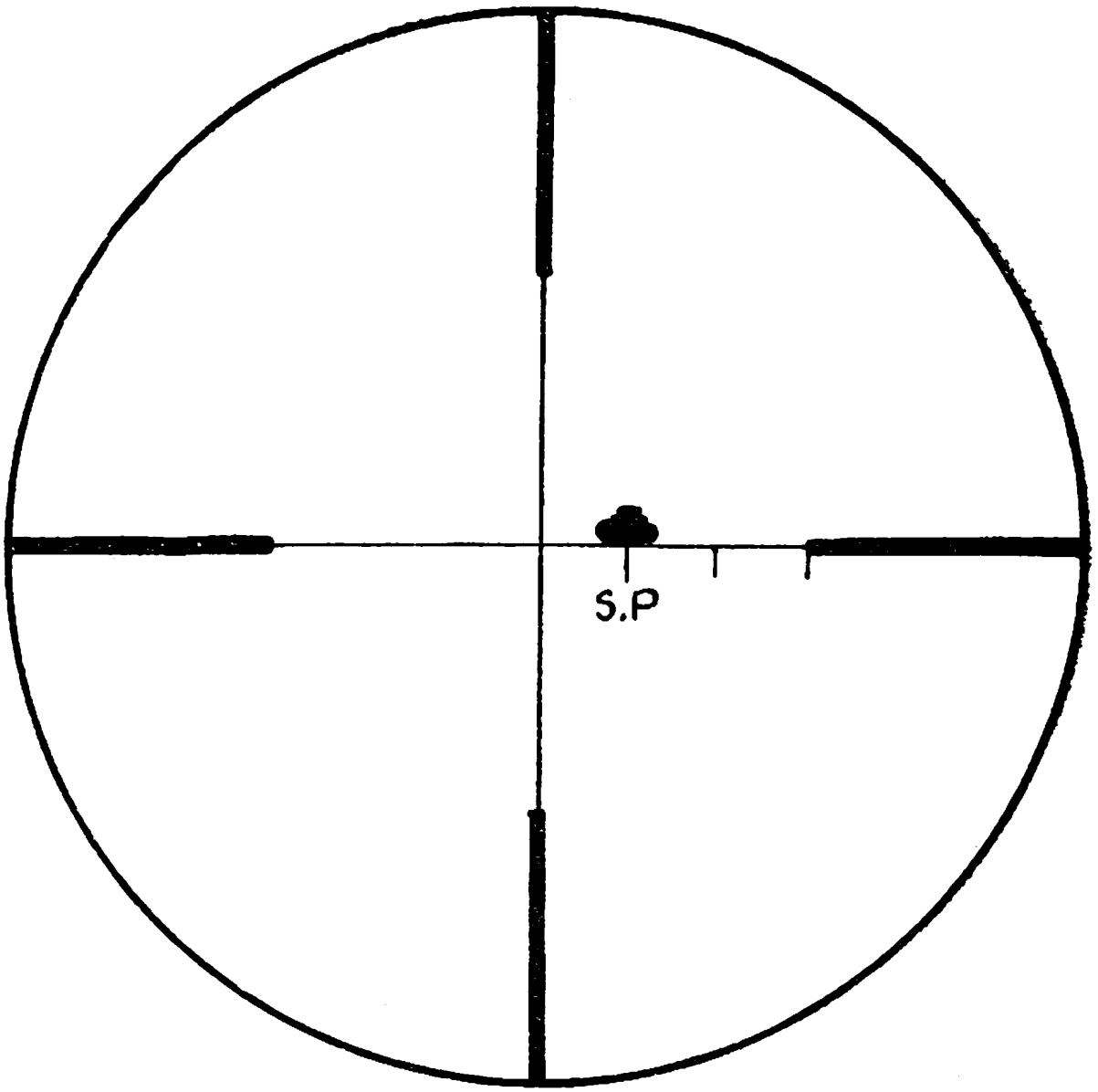
Fig. 8(A) (which gives the position of sight and target when the round left the gun), S.P. was 5 and right of the cross-wires, E.P.I. the target. A hit should have

Fig. 8(A).



resulted. When the shell burst, the wires were in the position shown in Fig. 8(B), and the burst appeared to be 5 right of the E.P.I.

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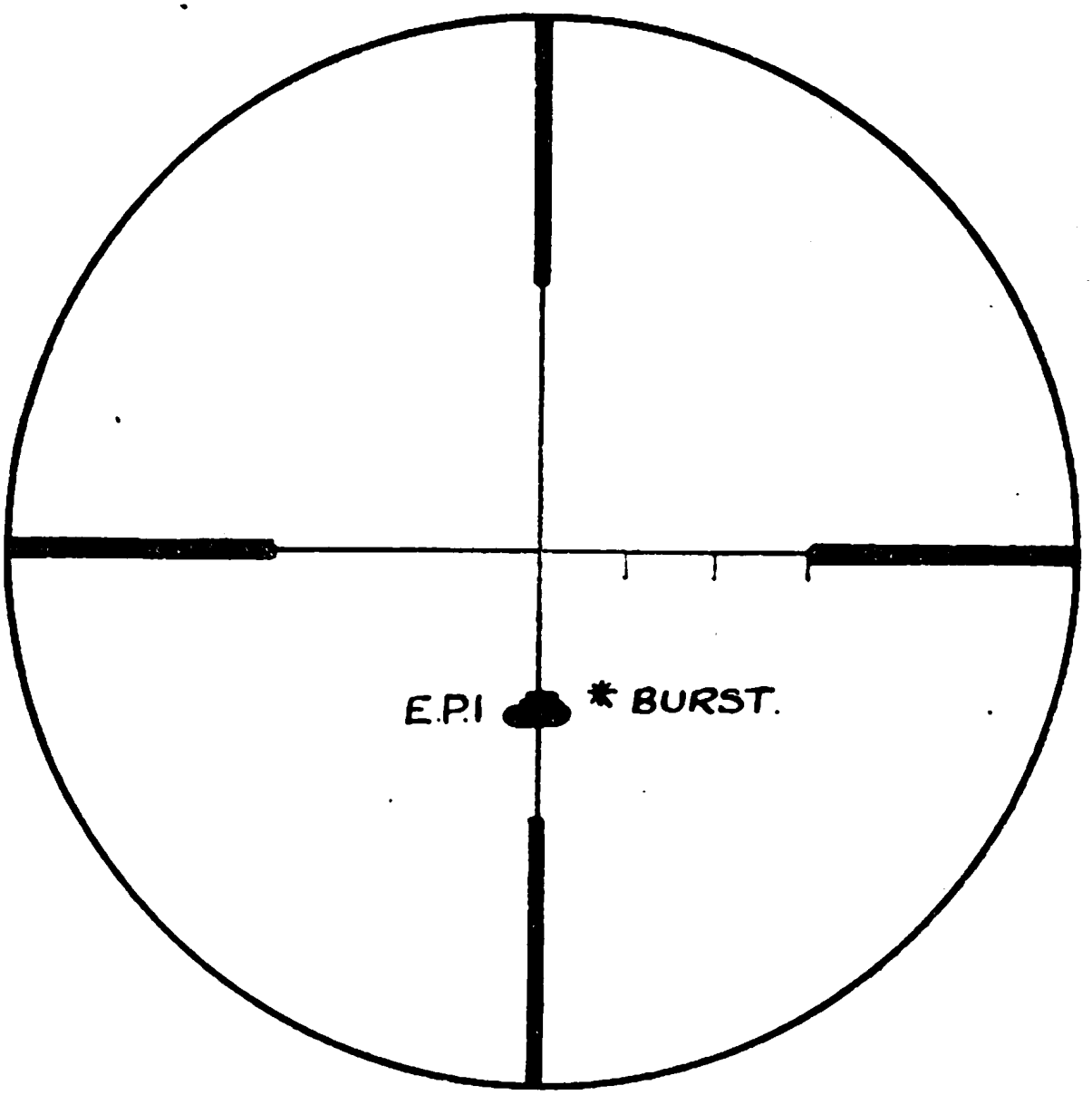
Therefore the correct S.P. for the round should have been 5 more right, *i.e.* 10 and right of the cross-wires.

Fig. 8(B)



If conditions have not changed, this will be the S.P. for the next shot.

6. *Correction for alteration of range.*—Movements of

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the tank and target, other than broadside movements, make it necessary to alter range between successive shots, *e.g.* when a tank and target are directly approaching each other, both moving at 5 m.p.h., the range decreases at the rate of 5 yards a second, and assuming the rate of fire to be 1 round in 10 seconds, the range will shorten by 50 yards between each round.

This correction should be applied by aiming up or down the vertical wire until the total correction of 300 yards. The range drum will then be adjusted by 300 yards and aim taken again on the horizontal wire.

When the gunner is firing at 2, 4, 8 or 10 o'clock, the alteration of range, due to own speed, is half the amount it would be if moving directly towards or away from the target.

7. *Correction for alteration of conditions of aim-off.*— Alteration of *aim-off* is rendered necessary by any alteration either of speed or course in tank or target.

With tracked vehicles, speed and course alter very rapidly, consequently as soon as the gunner becomes aware that a change has taken place in any of these factors, he must re-estimate his *aim-off* according to the new conditions, bearing in mind any information obtained from the rounds fired.

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CHAPTER III

VISUAL TRAINING

12. *General*

The principles of EYE TRAINING are explained in Chapter IV, Tank Training, Vol. I., 1930. The following sections refer to the application of these principles to tank gunnery training and to methods by which tank gunners can be trained to use their eyes intelligently and accurately.

13. *Phases of visual training*

The following are the principal factors to be dealt with in training :—

i. *Personal* :—

(*a*) Ability to judge distance from the interior of a rapidly moving vehicle without instrumental aid.

(*b*) Ability to judge the speed and angle of target movement.

(*c*) Ability to judge speed and direction of movement of own tank.

(*d*) Ability to identify different types of armoured fighting vehicles and thus to be able to pick out and hit an enemy in the excitement and confusion of a tank combat.

ii. *Topographical* :—

(*a*) Military vocabulary. It is essential to practice the use of the terms given in Sec. 17 through larynga-

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phones so that all ranks will be able to identify the feature referred to when fire orders are being issued in a moving armoured fighting vehicle.

(*b*) Examination of ground and detection of service targets under the limitations imposed by armoured fighting vehicles.

iii. *Aiming off.*—The methods used at present have been described in Chapter II, but practice is required in order that the practical application of the theory may be grasped by the tank gunner. (*See* Sec. **19**.)

iv. *Fire orders.*—The principles and method of issue are described in Chapter IV. Constant practice is necessary.

Opportunities present themselves in all phases of tank gunnery training, but the teaching of the subject will be regarded as a part of visual training. (*See* Sec. **20**.)

14. *Judging distance*

1. Distances may be judged :—
   - i. By measuring the intervening ground with the eye in terms of some familiar unit, such as 100 yards.
   - ii. By the apparent size of the object if it is known. (Visual angle.)
   - iii. By the visibility of the object as affected by light, atmospheric effect, background, etc.

2. All methods should be practised until distances can be approximately judged from the general impression conveyed to the eye, but the observer must bear in mind that this judgment may be influenced by certain conditions of ground, light, etc., which are mentioned later.

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3. The recruit will first be familiarized with landscapes in miniature representing ranges of 500, 1,000, and 1,500 yards in comparison with armoured fighting vehicles. He will be required to remember the results of his observations, and be given further opportunities of seeing armoured fighting vehicles in varying conditions of light, atmosphere, and background.

4. He will afterwards be taught the influence exercised by the ground, the features in the landscape, on general impressions of distance :—

i. Range of objects is liable to be over-estimated by untrained men :—

(*a*) When observing from an armoured fighting vehicle.
(*b*) When both background and object are of a similar colour.
(*c*) On broken ground.
(*d*) When looking over a valley or undulating ground.
(*e*) In avenues, long streets, or ravines.
(*f*) When the object lies in the shade.
(*g*) When the object is viewed in mist or failing light.
(*h*) When the object is only partially seen.
(*i*) When heat is rising from the ground.

ii. Range of objects is similarly liable to be under-estimated :—

(*a*) When the sun is behind the observer.
(*b*) In bright light or clear atmosphere.
(*c*) When both object and background are of different colours.

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(*d*) When the intervening ground is level or covered with snow.
(*e*) When looking over water or a deep chasm.
(*f*) When looking upwards or downwards.
(*g*) When the object is large.

5. Practice will follow in judging the distance of natural objects, features of ground and targets, reasons being given for his estimates by each observer, and the local conditions being carefully observed and explained by the instructor before passing to the next object.

6. As progress is made the time allowed for judging distances should be reduced, but rough guessing is never to be allowed. Frequent practice in observation from within the closed tank is important.

7. All ranks should be given occasional opportunities of revising their impressions of targets and natural objects at known distances and should be encouraged to use large-scale maps and air photographs as a guide in judging.

8. Field sketching and reconnaissance afford excellent training in judging distance.

9. Tests of judging distance will be carried out periodically in accordance with Handbook of Weapon Training, R.T.C.

15. *Judging speed and course of own vehicle*

Opportunities will present themselves during the movement of armoured fighting vehicles on tactical training when the crew commander may cross-question members of his crew as to the speed of the vehicle and

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the angle of its path with the line of fire to a previously selected aiming mark. By the use of such opportunities only can the ability of the gunners to judge the speed and course of their own vehicle be cultivated. Without such ability, the full fire effect of the vehicle in action is unlikely to be achieved.

16. *Judging speed, range and course of other vehicles*

1. Similar opportunities may be used by crew commanders to afford their crews practice in judging the speed, range, and course of distant vehicles.

2. The method of teaching the subject is described in Sec. **43**, 2, ii, Tank Training, Vol. I, 1930.

3. The problems may also be produced under " true to scale " conditions in a miniature-range landscape equipped with a gantry for moving targets electrically at known speeds.

4. The knowledge of theoretical *angles of aim-off* for given speeds and courses is of no avail unless the gunner is able to estimate such speeds and courses with accuracy by eye.

17. *Military vocabulary*

1. *General instructions.*—Practice in the use of this vocabulary will to a great extent be carried out through the laryngaphone so that the gunner is able to identify descriptions of features through this medium.

Its use will also be practised by crew commanders with their own crews, so that the crew become accustomed to the tone of voice and modulation employed by their own crew commander.

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2. *List of terms to be used :—*

i. *Targets (description and meaning).—*

Hornet	=	Hostile armoured fighting vehicle.
Ant	=	Anti-tank gun.
Maggie	=	Machine-gun.
Cav	=	Mounted troops.
Men	=	Infantry.
Transport	=	Enemy transport, whether mechanical or horse.
Hawk	=	Enemy aeroplane.
Trench	=	Any troops under cover.
Dugout	=	Any defended post occupied by troops.

ii. *Artificial features.—*

Footpath.
Ride.
Track.
Cross-roads.
Road junction.
Fenced.
Unfenced.
Fences. (Post and Rail. / Wire. / Iron. / Hurdles.)
Chimney.
Chimney stack.
Factory.
Crane.
Obstacles.
Viaduct.
Culvert.
Cutting.
Embankment.
Canal.
Lock.
Ferry.
Ford.
Moat.
Windmill.
Gasometer.
Gable-end.
Thatch.
Tiled.
Slate.

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iii. *Colours.*—

White.
Black.
Yellow.
Brown.
Blue.
Green.
Red.

iv. *Natural features.*—

Fir.
Wood.
Copse.
Bush.
Gorse.
Cornfield.
Stacks.
Stooks.
Pond.
Lake.
Poplar.
Bushy-topped (Trees).
Hedgerow.
Plough.
Grass.
Stubble.
Ricks.
River.
Stream.

v. *Topographical.*—

Valley.
Ridge.
Horizon.
Knoll.
Saddle.
Fold.
Quarry.
Nullah.
Donga.
Clearing.
Salient.
Defile.
Crest-line.
Spur.
Slopes, forward and reversed.
Dead ground.
Concave.
Convex.
Cliff.
Gorge.
Ravine.
Sector of ground.

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18. *Examination of ground*

The methods of teaching the tank gunner the study of country are explained in Sec. **43**, Tank Training, Vol. I, 1930.

Where range facilities exist, practice may be given by concealing part of the crew in a dugout fitted with a periscope and then detailing men to stalk a figure target erected near the dugout. Thus the observers learn to examine the ground closely and under similar conditions to those obtaining in a tank, and the stalker learns to make the best use of the intervening ground.

19. *Aim-off*

1. Practice is necessary in order that the gunner may be able to lay an *aim-off* as described in Chapter II.

The teaching of the subject will be divided into :—

i. Theoretical knowledge of the correct *aim-off* for given conditions.

ii. Ability to lay a previously estimated *aim-off* by use of practical methods.

2. In order to acquire a knowledge of the correct *aim-off* for given conditions, two Aldis telescopes will be linked in a bracket.

(The aiming rest used in musketry training lends itself to adaption for this purpose until a sealed pattern training store has been evolved.)

3. The lines of sight of the two telescopes are converged on to a miniature tank 12½ yards from the observers. Conditions of movement both in respect of platform and target are assumed, and the student is

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taught the correct *aim-off* for such circumstances. The instructor should remain seated behind one of the linked telescopes and call on a member of the crew to lay the necessary *aim-off* for a given problem.

4. Sequence of instruction for teaching *aim-off* :—

i. If the student has never been taught the subject before he should carry out a comparison of full size targets with the miniature models which are to be used in subsequent lessons.

A model made for use at 12½ yards is :—

(*a*) $\frac{1}{40}$ full size to represent armoured fighting vehicle at 500 yards.

(*b*) $\frac{1}{80}$ full size to represent armoured fighting vehicle at 1,000 yards.

(*c*) $\frac{1}{120}$ full size to represent armoured fighting vehicle at 1,500 yards.

ii. A lecture on the principles of *aiming-off*. (Sec. 9.)

iii. Instructors will verify that these principles have been appreciated by the students and that they understand why it is necessary to *aim-off*.

iv. An explanation of *aim by selection* ; how the horizontal wire of the telescope is divided into imaginary divisions so that the *selected point* can be such as to deal with any situation.

v. The instructor will explain that these divisions represent *angles* and that they are therefore applicable at all ranges up to 1,500 yards.

vi. The instructor will explain the theoretical effect of *angles of target movement* on the *aim-off*, and also the theoretical effect of *fling* when the gun is at various angles to the keel line of the tank.

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vii. He will then explain the practical method in use, namely, how assistance in estimating *aim-off* for *fling* is given in the first part of the fire order received. This will be followed by an explanation of the method of estimation, by the gunner, of the *aim-off* for the *angle of target movement*. The gunner has then merely to solve a simple sum to get the correct *aim-off* for the combined conditions.

viii. A problem will then be set to one of the students, who will be required to *lay* the required *aim-off*. The instructor will then allow the remainder of the crew to view the solution, questioning them as to its accuracy. Finally, he should show, if necessary, a correct solution to the problem.

20. *Fire orders*

Practice in the issue of fire orders is regarded as a part of eye training, since it involves skilful use of the eye both by the crew commander and his crew, and no opportunity of practice should be neglected.

Apparatus designed to afford crew commanders practice in the issue of fire orders under conditions approximating to reality is being evolved.

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CHAPTER IV

CREW CONTROL AND FIRE ORDERS

21. *General*

1. In order that crew commanders can effectively control their crews in action, it is essential that the system of orders throughout armoured units should be uniform.

2. The duties of the crew commander as regards control consist of :—

i. The receipt and acknowledgment of signals from his immediate commander.

ii. The control of the driver as regards course and speed.

iii. The control of the gunners as regards :—

(*a*) The selection and indication of targets.

(*b*) The giving of necessary data for the opening of fire.

(*c*) Opening and cessation of fire.

These duties require vigilance, initiative and decision on the part of the crew commander if he is to develop the full efficiency of his machine in accordance with the general plan of his commander.

22. *Fire orders*

1. A fire order is the form of words in which a crew commander conveys to his crew his decisions as to the application of the fire power of the tank.

2. The essentials of a fire order are :—(*a*) ACCURACY, and (*b*) RAPIDITY in order that the decisions of the crew commander may be materialized into projectiles on their way to the target.

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3. Rapidity and accuracy are obtained by :—

i. *Adherence to a definite sequence in the issue of orders.*—This prevents important omissions by the crew commander. It makes the order easier to understand, as the recipient knows what is coming next. He is, therefore, more likely to hear it correctly, remember it better and act on it quicker. The sequence is arranged so that the items are presented to the gunner in the order that he requires to know them.

ii. *Omission of all unnecessary words.*—This makes for brevity and for ease in remembering the order.

iii. *Use of the military vocabulary.*—The words laid down being easy to hear, are not subject to any misunderstanding.

iv. *Repeating back of the order* by the recipient to reveal any errors.

v. *Constant practice* of the crew in fire orders so that the form laid down becomes second nature both to the crew and to the crew commander.

4.—i. Fire orders must be (*a*) elastic, to deal with any situation which may arise under service conditions ; (*b*) simple.

ii. Tank targets vary from those engaged comparatively deliberately at ranges of about 1,500 yards, to surprise targets perhaps only a few yards away.

iii. At close ranges a rapid fire order is important. Great accuracy of range and *aim-off* is unnecessary. The fire order can consequently be abbreviated.

iv. Great care must be taken in the selection of suitable targets at long ranges, and careful control of ammunition expenditure must be exercised. Accuracy in the estimation of range and *aim-off* is necessary to obtain effective fire at these ranges.

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5. The crew commander has the best available observation and is therefore in a much better position to estimate speeds, ranges, and courses than men using telescopes and loopholes. Consequently he will maintain observation to the last possible moment, only taking cover temporarily when compelled to do so by concentrated small-arm fire. He will, when practicable, give all data to his gunners for their opening rounds. Consequently at long ranges, a full fire order is both possible and necessary for the proper control of fire. Gunners must, however, be able to estimate all the factors for themselves, as the crew commander may be otherwise occupied.

23. *Sequence and composition of a complete fire order*

(The following system of fire orders applies to tanks, Marks I, IA, II, and IIA. Modifications for other types of equipment will be issued as required.)

1. *Instructions to the driver.*—A situation requiring the opening of fire may sometimes necessitate a change of speed and course either to bring the most effective fire to bear, or for other tactical reasons. This order must be given first, for any change in the tank's movements after the gunner is on the target delays him and may even cause him to lose sight of his target.

The words used are :—

" DRIVER "—To call the driver's attention.

" QUARTER-RIGHT," or " HALF-RIGHT." " THREE-QUARTERS RIGHT," " RIGHT TURN " or " RIGHT ABOUT." Similarly with " LEFT."

" TEN "—Being the speed in miles an hour required.

If the order " RIGHT (or LEFT) WHEEL " is given the

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driver will continue to wheel, conforming with other tanks of the formation, until the crew commander gives "ADVANCE."

Even if no change of course or speed is necessary it is advisable to give the speed, as it informs the gunners as to the tank's future course and its speed for *aim-off* calculations.

2. *Weapons to be used.*—Only the gun named will fire, though the other gunner will follow the order and, if possible, pick up the target, so that he can open fire upon it at once if ordered.

The words used are :—

"THREE POUNDER."

"VICKERS."

"THREE POUNDER AND VICKERS."

"CO-AX." (Co-axial M.G. if fitted.)

These words also act as "calling up" words to draw the attention of the gunner concerned.

3. *Indication of target.*—This is a difficult task under tank conditions, but with good eye training, gunners are able to pick up targets that are visible to the crew commander if their eyes are directed to the right area.

This is done in three steps :—

i. Direction.
ii. Range.
iii. Description.

The first two factors get the man's eyes looking in the right direction, and finally the description of the target is given.

Direction of the target is indicated to the gunner by the clock code, combined, if necessary, with the traversing method.

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(*See* Crew Drill for Medium Tanks, Mks. I, IA, II, and IIA.)

4. *The range* is given :—

i. To get the gunner's eyes looking at a point approximately the right distance from the tank to assist him in identifying the target area.

ii. To give the gunner the range to put on his sight for the opening round.

E.g. " SIX HUNDRED." The word " YARDS " will be omitted.

5. *Description of target.*—The target will be described by the use of the military vocabulary. (*See* Sec. **17.**)

6. *Aim-off required.*—The gunners should always be trained to make their own estimation of *aim-off* and not to expect it from the crew commander, but, if the crew commander does include it in his fire order, the gunner will accept this estimate for his opening round.

The crew commander gives the *aim-off* by naming the position of the cross-wires relative to the target, *e.g.* :—

" AIM RIGHT TEN "=The 10 S.P. to the *left* of the cross-wires will be taken.

" AIM ON " =Cross-wires on the target.

7. *Executive order to fire.*—Unless there is any reason to delay the opening of fire, this will be given as a part of the order, without waiting for the gunner to report himself ready. He will then fire as soon as he has adjusted his sights and found his target; thus no favourable opportunity to fire is lost. The gunner cannot be expected to fire immediately on the order as he has often to wait for an opportunity to steady his sights on it.

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8. *The composition of a fire order in detail :—*

To whom addressed	Purport	Possible variations	Remarks
To the driver. (Executive order.)	To call attention.	"DRIVER."	
	The direction to proceed.	"QUARTER-RIGHT." "HALF-RIGHT." "THREE-QUARTERS RIGHT." "RIGHT TURN." "RIGHT ABOUT" and similarly for left.	On the order— "RIGHT ("LEFT") WHEEL" the driver will continue to wheel in conformation with the other tanks of the section until the word "ADVANCE" is given.
	The speed to proceed at.	"5." "10." "15." "20."	The words M.P.H. are redundant.
To the gunner. (Indicative order.)	The weapon to to use.	"THREE-POUNDER." "VICKERS." "THREE POUNDER AND VICKERS." "CO-AX."	The word "Gunner" is redundant.
	The direction to fire in	"ONE O'CLOCK." "TWO O'CLOCK." "THREE O'CLOCK." "FOUR O'CLOCK." "FIVE O'CLOCK." "SIX O'CLOCK." "SEVEN O'CLOCK." "EIGHT O'CLOCK." "NINE O'CLOCK." "TEN O'CLOCK." "ELEVEN O'CLOCK." "TWELVE O'CLOCK."	The direction of target from keel line of tank. If any alteration of course has been ordered the clock bearing given will be that which will be correct after the course has been altered.

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To whom addressed	Purport	Possible variations	Remarks
To the gunner. (Indicative order.)—*continued.*	The range to the nearest hundred yds.	"ONE HUNDRED." "TWO HUNDRED." "THREE HUNDRED." "FOUR HUNDRED." "FIVE HUNDRED." "SIX HUNDRED." "SEVEN HUNDRED." etc., etc.	(*a*) The word "Yards" is redundant. (*b*) To get the firer's eye looking at the required zone. (*c*) The range is put on the sight for the first shot.
	Nature of target.	"HORNET." "ANT." "MAGGIE." "CAV." "MEN." "TRANSPORT." "HAWK." } Code words. Or a natural, artificial or topographical feature described as in Eye Training. "AIM ON." "AIM RIGHT." "AIM LEFT." "5." "10." "15." "20."	
To the gunner. (Executive order.)	Order to fire.	"FIRE."	The order to fire is not to be delayed while the gunner repeats the order.

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As soon as the gunner has *identified his target* he will report " ON."

9. *To engage two targets.*—To engage two different targets separately, a separate fire order will be given to each weapon.

10. *In an emergency, e.g.* if an anti-tank weapon only 400 yards away opens fire suddenly, the order will be reduced to :—

" CO-AX AND VICKERS, EIGHT O'CLOCK, FOUR HUNDRED, ANT—FIRE."

11. If the gun is already pointing in the approximate direction, the clock ray may be omitted, but the range should always be included to direct the man's attention to approximately the right area.

Example :—" CO-AX AND VICKERS, FOUR HUNDRED, ANT—FIRE."

12. At intermediate ranges it will usually be advisable to give a full fire order, with the exception of the *aim-off*, which should only be given when there is ample time, and will normally be left to the gunner.

13. If the initial estimates of range and *aim-off* given by the crew commander prove inaccurate, the gunner must correct them without further orders.

14. As a rough guide, the *aim-off* should not be given under 1,000 yards, and the " Instructions to the driver " should be omitted at ranges under 400 yards unless it is actually required to alter the course of the tank.

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24. *Secondary fire orders*

1. "STOP" means "Stop firing," and after this order no gun will fire again until the order "GO-ON" is given. The order "STOP" is given :—

i. To stop one or more weapons from firing.
ii. To give an order during firing.
iii. To engage a fresh target.

On the order "GO ON" the gunner will continue on the same target unless another has been given.

2. *Orders during firing.*—An order during firing is necessary :—

i. When the crew commander observes that the projectiles are consistently missing the target. This is probably because the gunner cannot observe his rounds.

The crew commander will order "STOP"; a correctional order by the INRA method (*see* para. 5, below); and "GO-ON."

ii. When the wrong target is engaged. The crew commander will order "STOP."

(*a*) If the error is chiefly for line he will correct by the traversing method. (*See* para. 4, below.)

(*b*) If the error is chiefly for range, give a correctional order by the INRA method.

(*c*) When the gun concerned is a hull Vickers gun, he may use the 3-pounder to indicate. (*See* para. 6, below.)

iii. When the gunner has not picked up the target from the original fire order and has not opened fire.

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The crew commander will either :—

(*a*) Use the traversing method, for 3-pounder or co-axial M.G.

(*b*) Amplify his target description.

3. *Gun control.*—If the crew commander wishes the gunners to pick up and engage targets at their own discretion he will give the order " GUN CONTROL." This will apply to all the guns unless the order is preceded by the name of a weapon, when it will apply to that weapon only.

He may reassume control of one or all weapons at any time by the order :—

" 3-POUNDER "<br>" VICKERS "<br>" CO-AX " } " STOP," followed, if necessary, by a fresh fire order and " GO-ON."

4. *The traversing method.*—The crew commander from the turret or control post can tell fairly accurately at what target the gun is pointing.

If, after a fire order the gunner does not immediately pick up the target, the crew commander will order " TRAVERSE RIGHT " (or " LEFT ") until he sees that the muzzle is pointing towards the target. He then says " ON."

The normal fire order will always be completed before the traversing method is brought into use, since the gunner must have his range on his sights, and know the nature of the target, before he is finally brought on.

5. *The Inra method.*—This is a method of describing a target from a given reference point. (*See* Fig. 9.)

The diagram represents an imaginary circle on the

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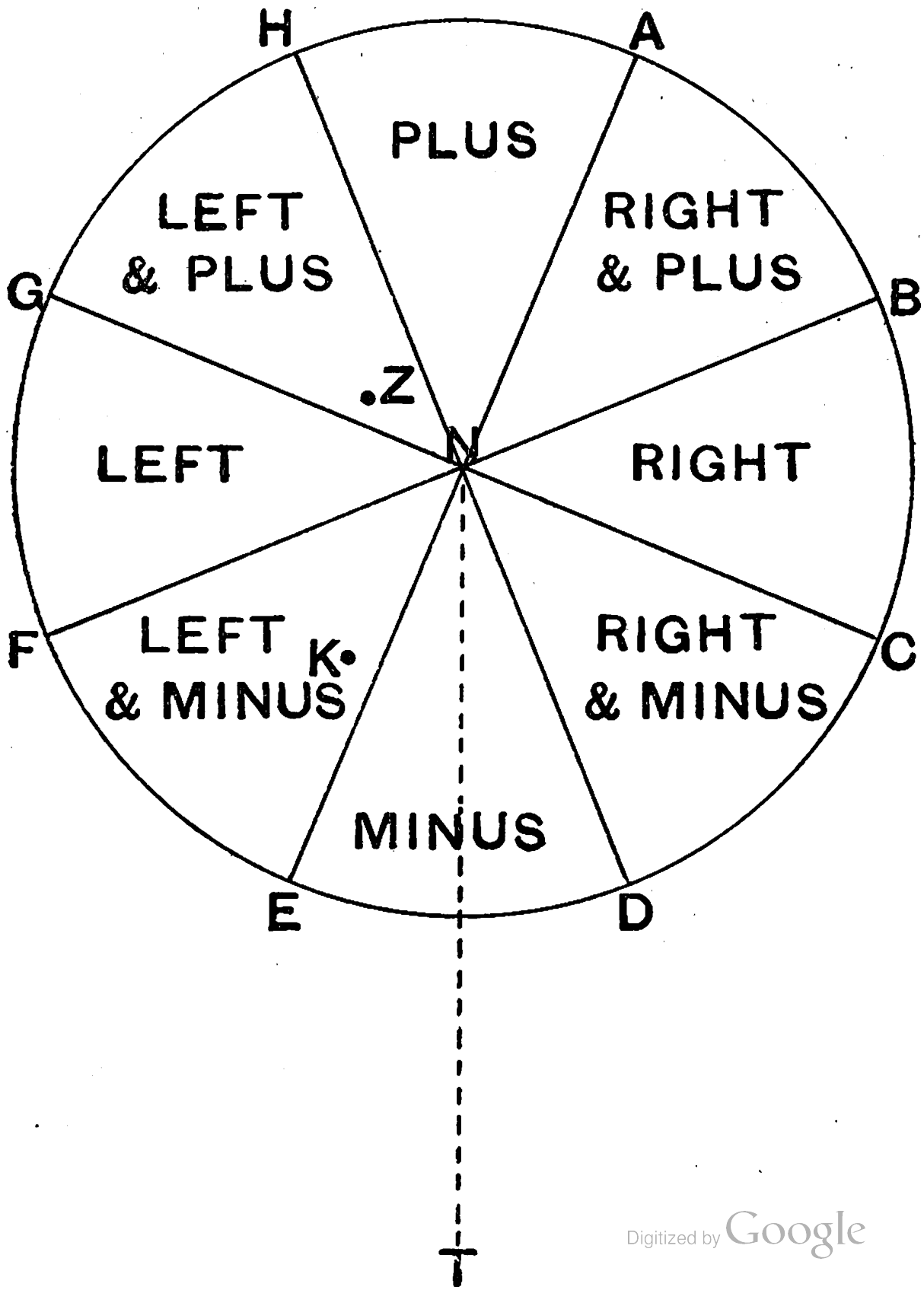
Fig. 9.



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ground, N being the reference point and TN the line of sight from gun to reference point :—

A target in the sector HNA is described as PLUS.

" " " ANB " " RIGHT & PLUS.

" " " BNC " " RIGHT.

and so on round the circle.

The distance from the target to the reference point is estimated in yards.

Thus the point K will be described as LEFT and MINUS 75 (yards).

The method is used in two ways :—

i. When a shot has fallen fairly near the target, its burst may be taken as the reference point and the actual target described from this, *e.g.* "FROM BURST—LEFT AND PLUS FIFTY," *i.e.* the gunner should shift his point of aim to the point Z in the diagram.

ii. If a target is very difficult to see or only momentarily visible, an easily distinguishable object may be indicated in the fire order, and this point used as a reference point, *e.g.* "FROM RED COTTAGE—RIGHT AND PLUS 150—ANT."

This method must be used with caution in a tank.

Only obvious and unmistakable objects will be used for reference points, and there must be no similar object within the clock ray, or 30 degrees.

6. *Indication.*—A target may sometimes be indicated to the machine gunner by firing a shell at it from a 3-pounder gun.

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The same fire order is given to both guns. When the shell is fired the Vickers gunner watches for the burst, picks up the target and immediately opens fire.

Example :—" DRIVER TEN," " VICKERS AND 3-POUNDER, INDICATE, FOUR O'CLOCK," " EIGHT HUNDRED," " MEN "—" FIRE."

If the Vickers gunner sees the burst, he will report " OBSERVED," and when he has picked up the target he will report " ON," and will immediately open fire without further orders. The crew commander will then give, " 3-POUNDER—STOP."

If the Vickers gunner did not see the shell burst, he will say " NOT OBSERVED." The crew commander will give " 3-POUNDER—REPEAT," when another shell will be fired.

If the round does not go very near the target, the crew commander will either give an INRA correction from the burst, or order another round to be fired.

The 3-pounder in this method also acts as a range-finder. If the gunner finds, from observation, that the crew commander's range estimation is inaccurate, he will report this to the crew commander, who will give a corrected range to the Vickers gunner.

7. *Fire for observation.*—When the 3-pounder gun is being used to indicate and the gunner has reported his inability to pick up the target, the crew commander will get him on as accurately as possible by the traversing method, and will give " 3-POUNDER FOR OBSERVATION—FIRE."

The gunner will then fire on this line and at the range previously given, steadying his sights on some point of aim on the ground, and will carefully note the burst

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of the shell. If the round falls near enough to the target, an INRA correction will be given. If necessary, another round of 3-pounder may be fired.

8. *Reporting targets to the crew commander by the crew.*—Any member of the crew observing a possible target will report it to the crew commander.

The following sequence will be observed :—

i. The word " TARGET."
ii. Direction of target by clock ray.
iii. Estimated range.
iv. Code word or other description of target.

The crew commander will acknowledge by the words " TARGET SEEN," followed, if he requires the gunner concerned to engage the target, by the word " ENGAGE."

25. *Issue and acknowledgment of orders*

1. Orders will be issued in a low, distinct, unhurried voice. Each word must be clearly enunciated.

The orders will be issued and repeated as follows :—

Order	*Repetition*
" DRIVER TEN."	" DRIVER TEN."
" THREE-POUNDER."	" THREE-POUNDER."
" FOUR O'CLOCK."	" FOUR O'CLOCK." (The gunner immediately starts to turn the turret.)
" SIX HUNDRED."	" SIX HUNDRED." (He puts on the range.)
" HORNET."	" HORNET."
" FIRE."	" FIRE."

The gunner will report " ON " whenever he *picks up* a target described, but the crew commander will *not*

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normally delay the order " FIRE " until he has heard the word " ON."

It will be a principle that every time a man looks along the sights he is directed to do so through the medium of a correct fire order.

CHAPTER V

THE IMPACT OF PROJECTILES ON BULLET-PROOF PLATE

26. *General*

1. Protection by bullet-proof plate being a characteristic of armoured fighting vehicles, those who fight in them should realize the degree of resistance the plate affords against different weapons and for various ranges and angles of impact.

2. Continual progress is being made in the manufacture of bullet-proof plate and in the design of weapons and projectiles with which to attack it. The penetrative power of various types of ammunition and the degree of resistance offered by different types of plate are continually changing. The following remarks are, therefore, subject to modification as time goes on.

3. When a projectile strikes a plate one or more of the following will happen :—

(*a*) Penetration.
(*b*) Splash.
(*c*) Flaking.
(*d*) Shearing of nuts and bolts.

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27. *Penetration*

1. The power of a projectile of a certain weight to penetrate a given thickness of plate depends on certain factors of which the main are :—

(*a*) Hardness of projectile.
(*b*) Its shape.
(*c*) Angle of impact.
(*d*) Striking velocity.

If the above factors are constant, broadly speaking, the thicker the plate the heavier is the projectile required to penetrate it.

2. *Hardness of projectile.*—Where the projectile is armour piercing and has a hardened steel core, the hardness of the core, particularly of its nose, is of great importance, the best hardness depending on the quality of the steel used.

3. *Shape of projectile.*—There is a particular shape of pointed head which has been found by experience to be the best to give penetration at large angles of impact. Certain other shapes of head give better penetration at very small angles of impact, but are less effective at large angles of impact. A pointed head is usually adopted as giving best all-round performance.

4. *Angle of impact.*—The larger the angle of impact the more likely is the projectile to penetrate. When a projectile strikes a plate directly broadside or nearly so, the angle of impact depends on the muzzle velocity and the range. (*See* Fig. 10.)

When a projectile strikes a plate not broadside, but at an acute angle, the angle of impact in the horizontal plane is small, and consequently the likelihood of penetration

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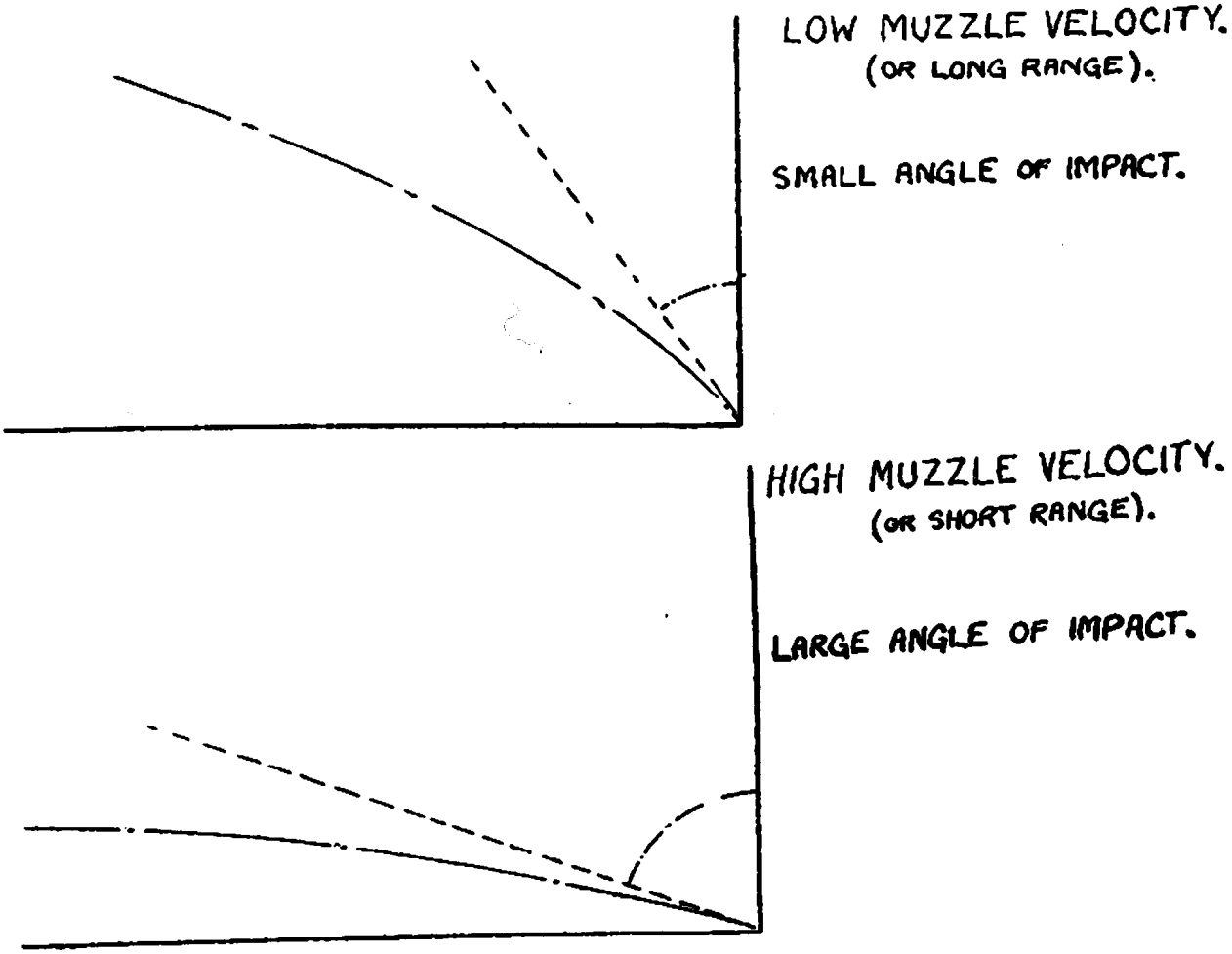
is reduced. To put the matter in simple language, a glancing blow is less likely to penetrate than a direct blow.

Fig. 10.



5. *Striking velocity*.—The striking velocity of the projectile depends upon :—

i. Muzzle velocity.
ii. Range to target.
iii. Type of projectile.

For example a heavy projectile loses velocity more slowly than a light one, and so on. (*See* Sec. **2**, 5.)

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6. *Action subsequent to penetration.*—After a hard projectile has succeeded in penetrating the plate, its remaining velocity, though reduced, is usually considerable, but it is almost invariably turning over, that is, it is no longer flying nose first. If the projectile, therefore, meets a second plate and its velocity is sufficient, it will smash the second plate and pass through this also, but if the velocity is insufficient it will bounce off the second plate and ricochet round the space between the two plates.

28. *Splash*

1. Soft bullets liable to *splash* on a plate are usually composed of a lead core inside an envelope of a harder material, such as steel or cupro-nickel. When such a bullet *splashes* on the plate it is probable that the lead is transformed by the local heat of impact into gas at comparatively high pressure and this gaseous lead spreads along the plate or through any cracks or joints there may be in the plate, and being gas it is capable of changing its direction wherever an outlet for the pressure can be found. It is possible, therefore, for such lead *splashing* to penetrate through cracks in armour, even when the crack is some little distance away from the point of impact.

The envelopes of such bullets also break up and *splash* along the surface of the plate, but the particles are not transformed into gas and are not capable of changing their direction in the same way as the lead.

2. These *splash* particles may cause injury to the eyes, but are not otherwise likely seriously to affect

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the man. The moral effect of *splash* in tanks not entirely proof against it, must, however, be taken into account.

29. *Shearing of rivets and bolts*

Rivets and bolts projecting on the exterior of the armour of an armoured fighting vehicle are liable to be sheared off when the plate is struck by bullets which do not penetrate. If, as is often the case, such rivets and bolts are made of soft steel, they are liable to damage by lead-cored projectiles and may be driven through into the interior.

30. *Flaking*

When projectiles strike bullet-proof plate, they are liable, if the plate is too brittle, to cause fragments of the plate to chip from the inner face of the plate.

These fragments are known as *flakes*, and may possess sufficient velocity to injure the crew or to damage fittings.

It follows that although hardness is a desirable characteristic of a bullet-proof plate, this must be allied with toughness, particularly on the back surface, and brittleness must, in all circumstances, be avoided.

31. *Asbestos lining*

The interior of some types of armoured fighting vehicles is lined with a type of asbestos with the intention of :—

i. Preventing *splash* and *flaking*.
ii. Preventing pieces of rust or paint being chipped away from the inner face of the plate and thus causing injury.
iii. Keeping the interior of the vehicle cool.

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32. *Weight of plate*

The weight of the bullet-proof plate required to afford complete all-round protection to an armoured fighting vehicle and its crew is very considerable.

The weight depends on :—

i. The superficial area to be protected.
ii. Thickness of the plate. (1″ thickness of plate weighs 40 lb. a square foot.)

The superficial area to be protected cannot be reduced below certain limits dictated by the size of the vulnerable parts of the vehicle, such as the engine and fighting chamber.

It follows that the thickness must be determined by the necessity of balancing the degree of mobility required from the vehicle while rendering it as far as possible immune from attack by small-calibre projectiles likely to be fired at it.

An armoured fighting vehicle is accordingly fitted with bullet-proof plate, *i.e.*, plate proof against an armour-piercing bullet of a particular calibre striking it at some stated velocity.

33. *Effect of manœuvre*

The bullet-proof plate is less liable to penetration when the armoured fighting vehicle manœuvres so as not to offer normal impact to the projectiles. This factor will undoubtedly influence tank fire tactics to a considerable extent when armour-piercing projectiles are used by the enemy.

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34. *Armour-piercing bullets*

The production of armour-piercing bullets of any calibre entails considerable manufacturing difficulties; at present each bullet has to be turned up on a lathe. It is unlikely that any nation at war will be able to produce them in sufficient numbers to meet the demands of its armed forces. Their use in war may not be so general as might, at first sight, be expected.

The use of this type of projectile also entails considerable wear and tear to barrels, and causes inaccuracy to develop quickly.

35. *Description of plate*

1. Each individual plate, before being finally built into an armoured fighting vehicle, is put through a rigorous proofing test by the military authorities.

2. The difference in resistance offered to projectiles by bullet-proof plate and shrapnel helmets (made of manganese steel) is as follows :—

i. Bullet-proof plate being comparatively thin is unable to bend to any great extent. It stops the projectile either on impact with the surface or, by absorbing its energy, after it has penetrated somewhat.

ii. Shrapnel helmets being comparatively thin only resist projectiles possessing low velocity. The steel is capable of being bent considerably before it suffers fracture. It absorbs the energy of the bullet by bending and thereby prevents penetration.

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36. *Gas*

Owing to their all-round armour protection, the crews of armoured fighting vehicles are less liable to casualties from gas than are unarmoured troops. It may be confidently anticipated that the protection thus afforded is likely to be improved in future designs of armoured fighting vehicles.

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